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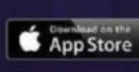
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WELCOME



Dinosaurs seem to be having a bit of an image crisis of late. On the one hand, the silver screen offers up the dinos we know and love – reptilian and full of roars – while on the other, scientists are building completely new pictures of what these prehistoric beasts looked like. You'd think the palaeontologists would be happy, fed on a glut of new fossils, imaging and sampling technologies, but they're not. Barely have they finished one

theory, or a visualisation, before some new piece of evidence comes to light that they have to factor in. Of course, I'm exaggerating, but I just want to stress what a golden age of dinosaur discovery we're in right now. To make sense of it all, we asked a scientist and writer at the front line of palaeontology to take a break from brushing off bones to reveal the biggest puzzles in the world of dinosaur research right now. Find out more on p36.

Cryonics – the science of using extremely cold temperatures to preserve human tissue – has also come on leaps and bounds in the last decade, so much so that one man in Texas wants to build the world's biggest facility dedicated to freezing human bodies. It's the stuff of science fiction, so we got in touch to find out his plans. Turn to p54 to see what he said.

Enjoy the issue!

Daniel Bennett

Daniel Bennett, Editor

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DR STEPHEN BRUSATTE

Stephen is a palaeontologist at the University of Edinburgh. He reveals the enduring mysteries that are baffling dinosaur experts today. → p36



JHENI OSMAN

Former *BBC Focus* editor Jheni is a science writer and presenter. She finds out how the world's happiest people keep smiling through the winter. → p68



DR ELIZABETH WHITE

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EYE OPENER

Tunnel vision

ZHEN YUAN

CHINA

This seemingly infinite corridor of books leads to the entrance of the Yangzhou Zhongshuge bookshop in Zhen Yuan, southern China. The avant-garde architecture is the creation of designer Li Xiang of Shanghai-based architects XL-MUSE, and takes inspiration from the nearby Qiantang river.


Black tiles made from polished stone line the floor, which is intended to represent the reflective surface of the water. Meanwhile, the specially designed curved floor-to-ceiling bookshelves represent the many bridges that span the river.

"Yangzhou Zhongshuge is located in Zhen Yuan, which is next to the waterside and in front of the trees," says a spokesperson for XL-MUSE. "We added the arched bridge, an indispensable element of this historical and cultural ancient city, in our design concept as it used to be the guiding factor of culture and commerce. It represents that the bookstore is the bond between humans and books."

PHOTO: SHAO FENG/LI XIANG ARCHITECTS







EYE OPENER

Harsh climes

DANAKIL DEPRESSION,
ETHIOPIA

Seen here is the Dallol salt dome. It rises from the floor of the Danakil Depression – part of the East African Rift, and one of the hottest places on Earth – in northern Ethiopia. The Dallol salt dome lies at the heart of a system of hot springs, geysers, salt flows and oily lakes that give off acidic gas and smoke. The dome forms as briny water from springs evaporates when it reaches the surface, leaving the salts behind.

As conditions here are thought to be similar to those that prevailed on our planet when life first emerged, the area is of great interest to those studying 'extremophile' life forms. Until recently, scientific research in the area has been limited, due to the war between Ethiopia and neighbouring Eritrea. But January 2016 saw a team of ecologists, microbiologists, geologists and crystallographers spend two weeks gathering samples under military protection.

Since then, they've been busy analysing all the specimens they collected. All we know so far is that they can "confirm the presence of extremophilic microorganisms," but astrobiologists, in particular, will be waiting to read their findings with great interest.

PHOTO: OLIVIER GRUNEWALD

PHIL MCINTYRE ENTERTAINMENTS IN ASSOCIATION WITH SUE RIDER MANAGEMENT PRESENTS

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INCE**

PROFESSOR BRIAN COX

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

JANUARY 2017

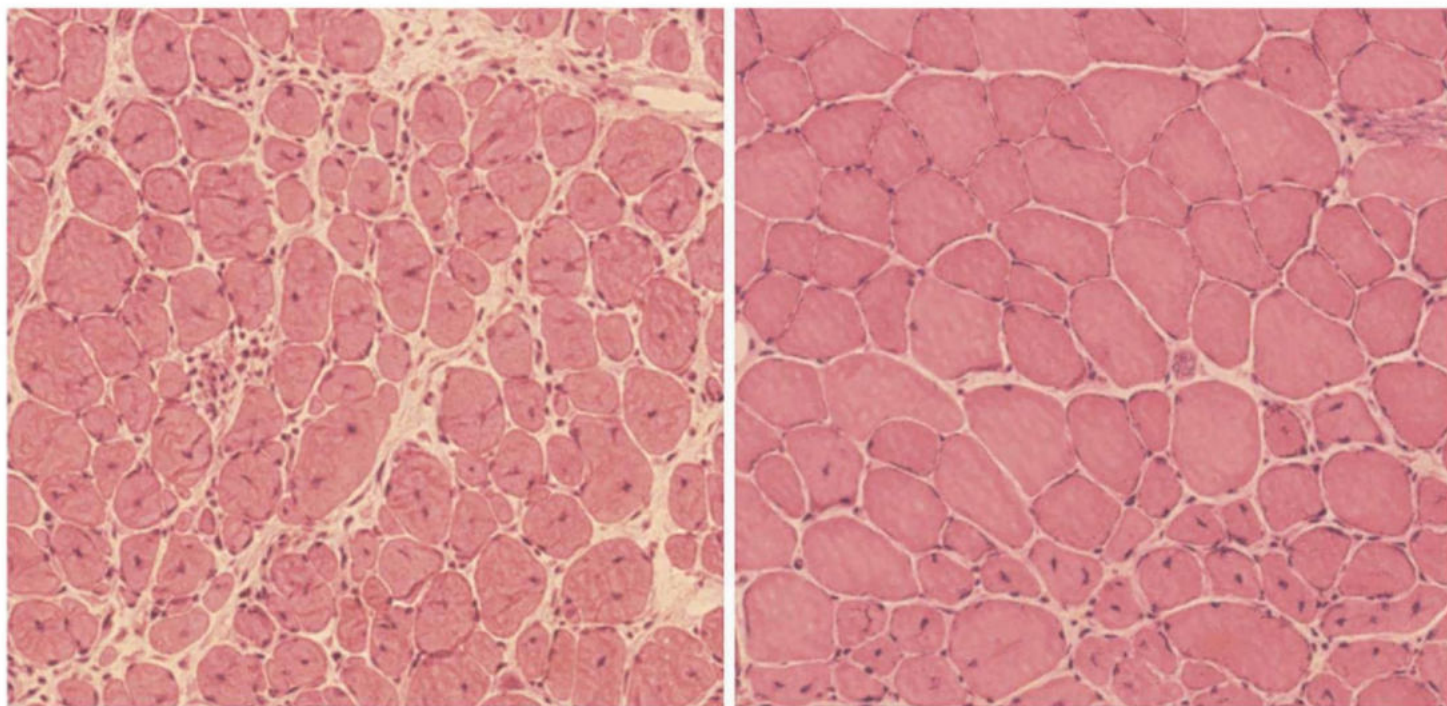
EDITED BY JASON GOODYER

GENETICS

SCIENTISTS REVERSE SIGNS OF AGEING

New genetic treatment using stem cells suggests
we can turn back the clock on old age

PHOTO: SCIENCE PHOTO LIBRARY



Muscle cells in old mice (left) underwent regeneration (right)

It has long been known that manipulating certain genes in an organism can slow ageing and extend its lifespan – but the creation of genetic techniques to safely halt or reverse age-related conditions in humans has so far proved elusive.

However, researchers at the Salk Institute of Biology in California have developed a new technique that could be a first step towards the medical world's fabled 'elixir of youth'.

The method, recently outlined in the journal *Cell*, involved 'switching on' four genes associated with stem cells. It appeared to reverse some signs of ageing in both human skin cells and live mice. The four genes, known as 'the Yamanaka factors', are often used by researchers wanting to turn any type of cell into unspecialised cells known as induced pluripotent stem cells (iPSCs). These cells are capable of dividing indefinitely and becoming any cell type present in the body.

Previous studies found that when cells are made to express Yamanaka genes and turn into iPSCs, they appear younger, having been stripped of the cellular markers of ageing as they revert back to a more fundamental cell type. Yet to induce cells to turn into iPSCs en masse in a live animal would mean many cells cease to function in the way organs need them to, causing organ failure and ultimately death.

However, researchers at the Salk Institute decided to try making cells express the Yamanaka factors cyclically, in bursts. The hope

“THIS STUDY
SHOWS THAT
AGEING IS A
VERY DYNAMIC
AND PLASTIC
PROCESS”

was that the cells would begin to experience some of the age-defying effects of the Yamanaka genes without actually turning into stem cells.

The researchers first tested this idea with skin cells from mice and humans. When they applied their method of cyclically turning on the expression of Yamanaka factors, the cells showed reversal of multiple ageing hallmarks, but did not lose their identity as skin cells.

Next, the researchers used the technique in live mice affected by progeria, a disease that causes accelerated ageing. After inducing the animals to express the genes in short bursts, their cardiovascular performance improved, as did the function of other organs, and the animals lived 30 per cent longer.

Crucially, the mice were not more likely to develop cancer, which is a fundamental drawback of many stem cell-based techniques.

Finally, the scientists turned their efforts to old but otherwise normal mice. In these animals, the technique led to an improvement in the ability of the pancreas and muscles to repair themselves, a key process that deteriorates with age.

“Obviously, mice are not humans and we know it will be much more complex to rejuvenate a person,” says Izpisua Belmonte, one of the study's co-authors. “But this study shows that ageing is a very dynamic and plastic process, and therefore will be more amenable to therapeutic interventions than what we previously thought.”

SPACE

SUN-LIKE STAR EATS PLANETS FOR BREAKFAST

It seems that planet-destroying Death Stars aren't just confined to *Star Wars* movies. Astronomers have discovered a solar system with a host star a lot like the Sun, and it appears to have swallowed up some of its planets.

The study, which was published in *Astronomy & Astrophysics*, focused on HIP 68468, a star about 300 light-years away with a mass roughly that of our Sun. These 'solar twins' are of great interest to astronomers because they can tell us more about the likely past, and future, of our own planetary neighbourhood.

Using the 3.6m telescope at La Silla Observatory in Chile, the international team of scientists discovered two potential exoplanets orbiting HIP 68468: a giant planet that's 50 per cent more massive than Neptune and a 'super-Earth', three times the mass of our own. Even

more intriguingly, analysis of the star's chemical composition revealed that it contains four times more lithium than would be expected for its age, as well as a high level of 'refractory elements' – heat-resistant metals that are abundant in rocky planets.

The most likely explanation for these unexpected elements is that the star has a history of ingesting planets, which would have deposited lithium and other metals in the stellar atmosphere. Taken together, the star's extra material is equivalent to the mass of six Earths.

So could the same thing happen in our own Solar System? "It doesn't mean that the Sun will 'eat' the Earth any time soon," explained Prof Jacob Bean, a co-author of the study. "But our discovery provides an indication that violent histories may be common for planetary systems, including our own."

IN NUMBERS

136

The number of different dance moves used by male flamingoes to woo females, as discovered by researchers in the south of France.

4kg

The average amount of weight gained by students during their time at university, as reported by researchers at the University of Vermont. The effect is due to poor diets and high rates of alcohol consumption, they say. No surprise there, then.

19m

The height of the biggest wave ever recorded. It was clocked by a buoy set up by the World Meteorological Organisation in the North Atlantic in February 2013 but was only recently officially recognised.

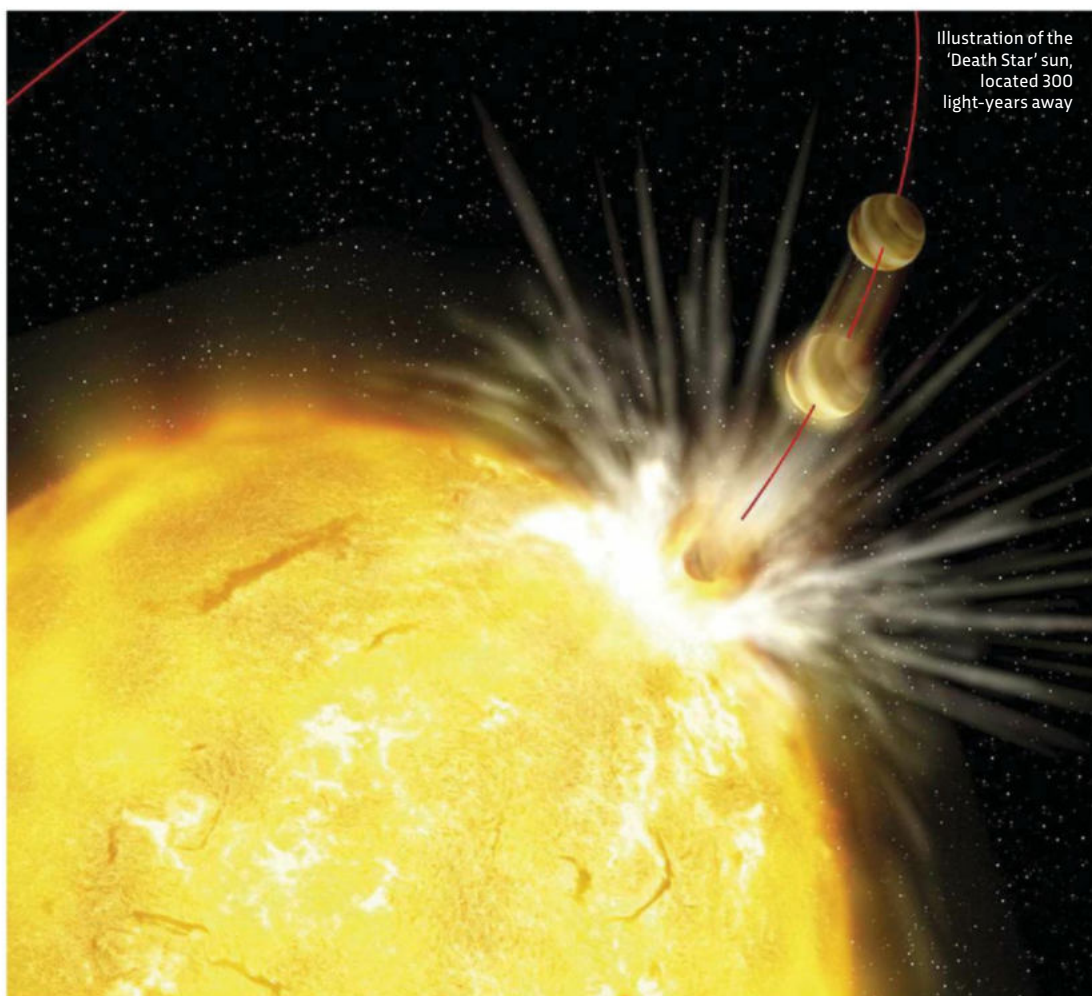


Illustration of the 'Death Star' sun, located 300 light-years away

DINOSAURS

DINOSAUR TAIL FOUND TRAPPED IN AMBER

This really is a telling tail: researchers from China, Canada and the UK have discovered a dinosaur tail, complete with its feathers, trapped in a piece of amber.

The tail, consisting of eight vertebrae surrounded by feathers, belonged to a juvenile bipedal dinosaur that was preserved in mid-Cretaceous amber about 99 million years ago. While dinosaur feathers have been found in amber before, earlier examples have been difficult to link to their source animal.

“We can be sure of the source because the vertebrae are not fused into a rod or pygostyle [a triangular plate that supports the tail feathers] as in modern birds and their closest relatives,” said researcher Ryan McKellar. “Instead, the tail is long and flexible, with keels of feathers running down each side. In other words, the feathers are definitely those of a dinosaur, not those of a prehistoric bird.”

After investigating the sample with microscopes and CT scanners, the researchers found that the tail probably had a chestnut-brown upper surface and a pale underside. Layers of soft tissue layer around the bones contain traces of ferrous iron, a relic left over from red blood cells trapped in the sample.

“Amber pieces preserve tiny snapshots of ancient ecosystems, but they record microscopic details, three-dimensional arrangements, and labile tissues that are difficult to study in other settings,” said researcher Ryan McKellar. “This is a new source of information that is worth researching with intensity, and protecting as a fossil resource.”

ENGINEERING

PARROT WEARING GOGGLES MAY HELP US BUILD ROBOTS THAT FLY MORE EFFICIENTLY

In order to investigate the lift generated by a bird's wings, a team from Stanford University trained a Pacific parrotlet called Obi to fly through a chamber filled with microscopic aerosol particles illuminated with lasers.

As he swooped through the air, the researchers were able to record the motion of the laser light that was scattered by the flapping of his wings. The goggles were specially designed to protect the bird's eyes and also had reflective markers on the side so the team could track his velocity.

The measurements revealed that the swirling vortices generated by the bird's wingtips break up in a sudden, dramatic fashion that current mathematical models of flight fail to account for.

According to the researchers, the results help explain the way animals generate enough lift to fly, and could have implications for how flying robots and drones are designed in the future.

"Many people look at results in the animal flight literature for understanding how robotic wings could be designed better," said researcher David Lentink. "Now, we've shown that the equations that people have used are not as reliable as the community hoped they were. We need new studies, new methods to really inform this design process much more reliably."

Obi can attract all the birds with goggles like these...



PHOTOS: RYAN MCKELLAR, ERIC GUTIERREZ/STANFORD UNIVERSITY

WHAT WE LEARNED THIS MONTH

SALTING ICY ROADS IS CHANGING THE SEX OF FROGS

Researchers at Yale University have found that chemicals used in de-icing salt can find their way into ponds and change the sex of frogs during the early stages of their lives. The proportion of females could be reduced by up to 10 per cent, potentially damaging some frog populations, they say.

DAYS ARE GETTING LONGER

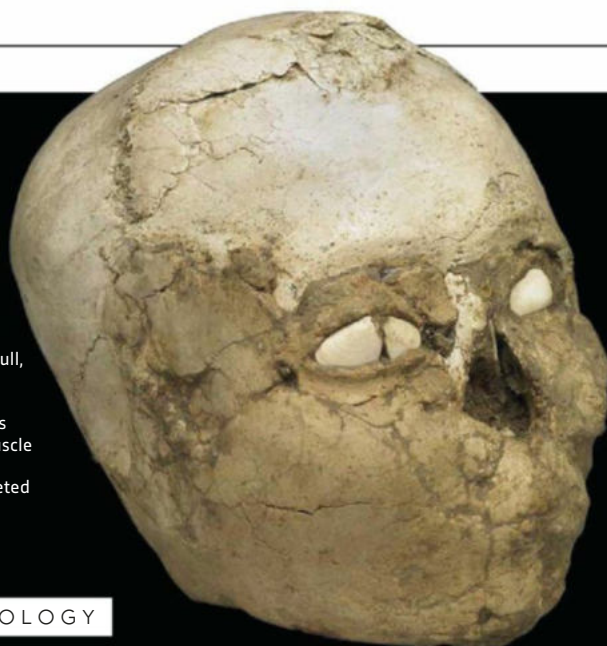
Have you ever moaned that there aren't enough hours in the day? Well, days will get an hour longer, a team at Durham University has found – just not for two million years. The effect is due to the Moon's orbit growing by around 4cm a year as the Earth's rotation slows.

'ANTACIDS' COULD HELP US FIGHT CLIMATE CHANGE

One key idea for combating climate change is to spray aerosol particles into the atmosphere to reflect the Sun's rays, but many of the compounds that would be suitable produce acids that damage the ozone layer. Now, a team at Harvard has found that calcite, a constituent found in many antacids, could reflect sunlight while absorbing harmful acids.

'MAN FLU' COULD EXIST

Men could be harder hit by certain infectious diseases, a team at Royal Holloway University has found. Some bugs have evolved to affect women less than men, so they can be passed on to children through breastfeeding or childbirth, the researchers say.



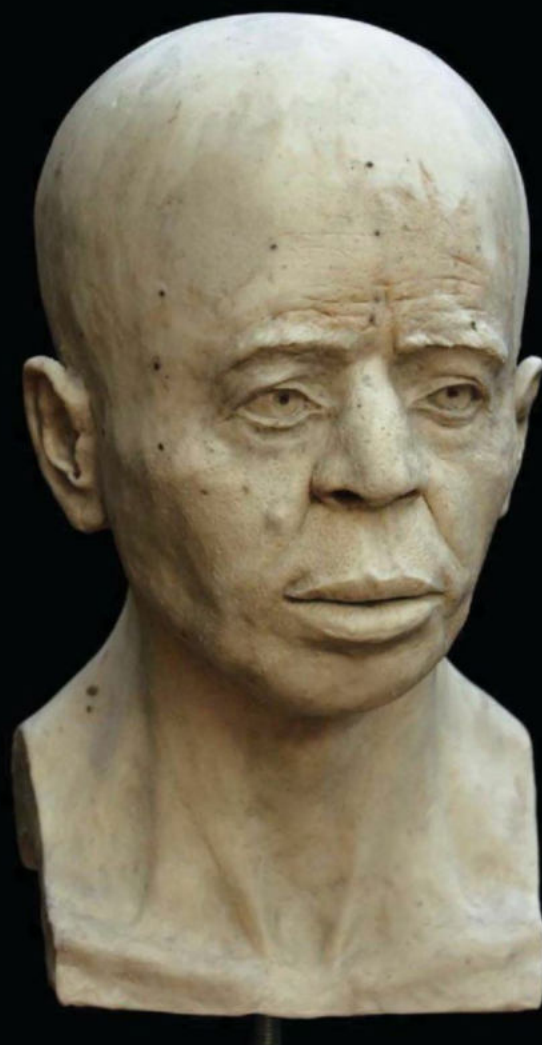
RIGHT: The Jericho Skull, covered with clay

FAR RIGHT: The face is rebuilt muscle by muscle

BOTTOM: The completed facial reconstruction

ANTHROPOLOGY

FACIAL RECONSTRUCTION OF NEOLITHIC MAN CREATED FROM ANCIENT SKULL

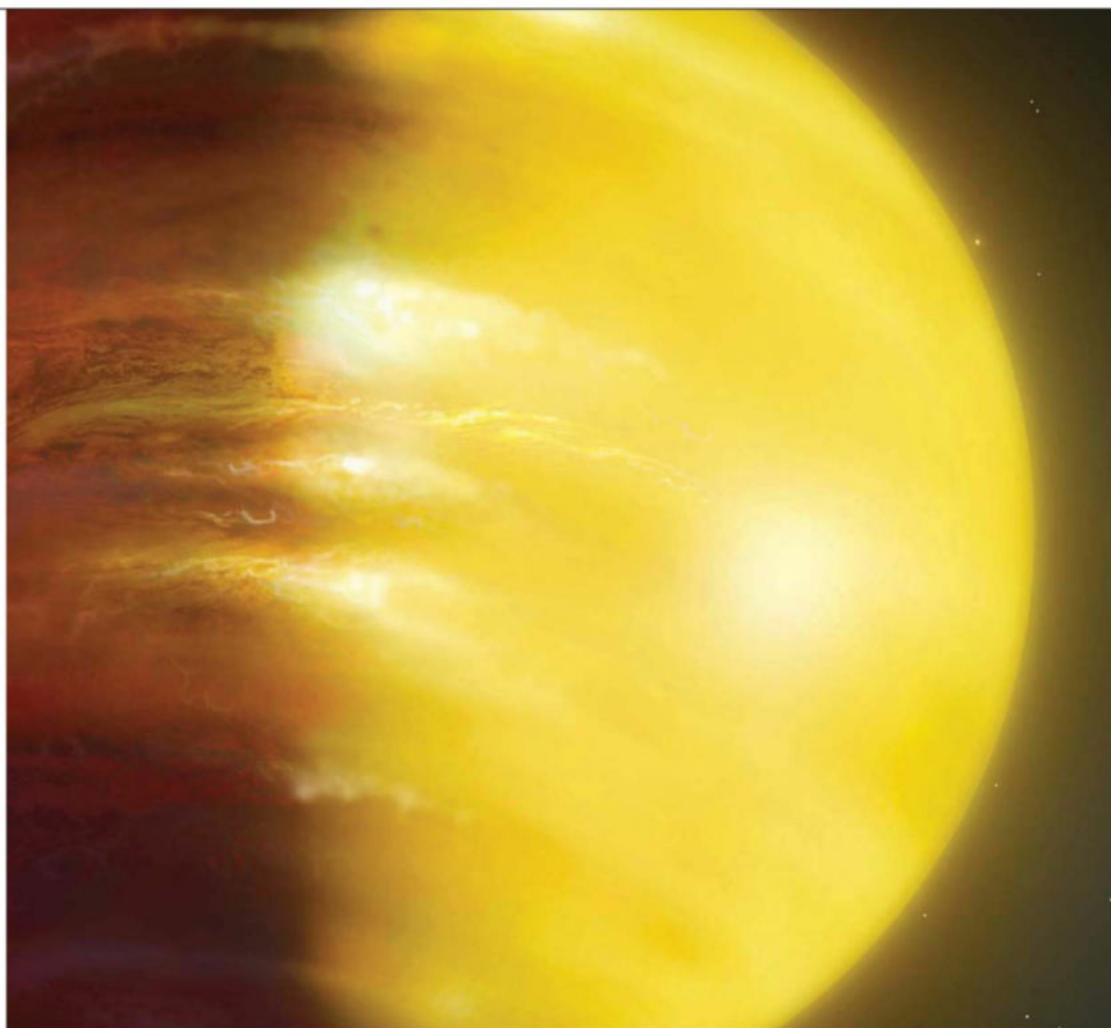


If you were to hop into a time machine to travel back 9,500 years to what is now Palestine, you just might bump into this guy. This head was painstakingly reconstructed by the Imaging and Analysis Centre at the Natural History Museum using 3D scans of the so-called Jericho Skull – a face modelled in plaster over a real human skull, which was discovered during excavations in the Middle East in 1953.

Plastered skulls are thought to have been an important part of Neolithic rituals that honoured the dead. The exact reason for this is largely unknown, but some archaeologists believe the skulls belonged to revered members of the community.

By using specialist micro-CT scanning techniques (a form of X-ray imaging in 3D), the researchers were able to examine the skull beneath the plaster in unprecedented detail. “First we had to digitally separate the plaster and soil from the CT scans using the computer, and then we 3D printed the bone part of the composition,” said Alexandra Fletcher, curator of the Ancient Near East at the British Museum. “That then went to a facial reconstruction expert a company called the RNDP Partnership – that’s Richard Neeve and Denis Smith. Richard Neeve developed this forensic reconstruction originally working with the police to identify unknown human remains. He had such success with this technique that people who had family members missing could be shown the reconstructed faces and recognise their relatives.

“In effect, if we could move someone through time from the Neolithic when this man lived and put them in a room with him, they would be able to recognise him, which is quite a thought.”



THE DOWNLOAD

The technosphere

What's that? London's latest orb-shaped nightclub perhaps?

I'm afraid not. It's an entity comprising all of the man-made objects on the Earth, including everything from houses and factories to smartphones and CDs. The concept was originally conceived by US researcher Peter Haff.

So how big is it?

Well, according to a new study carried out at the University of Leicester, the technosphere now weighs 30 trillion tonnes. That's 50kg for every 1m² of Earth's surface.

Wow. Tell me more...

The concept is based around the idea of the Anthropocene – the current geological age, viewed as the period in which human activity has been the dominant force on the climate and environment – and provides a measure of how much humans have changed the Earth.

So it's here to stay, then?

Yep. The team says items such as ballpoint pens or USB sticks could become preserved in layers of the Earth as 'technofossils', to be found in the distant future by geologists and used to help characterise and date the Anthropocene era.

ASTRONOMY

FIRST EXOPLANET WEATHER REPORT REVEALS VAST CLOUDS OF RUBIES AND SAPPHIRES

This really is a gem of a planet. A gas giant, located more than 100 light-years away and 16 times the size of Earth, has an atmosphere filled with giant swirling clouds containing the building blocks of rubies and sapphires, a team at the University of Warwick has found.

After combing through data sent back by NASA's Kepler mission, the team found that the light reflected from planet HAT-P-7b changed over time, which is an indicator of the presence of strong winds blowing the atmosphere across the planet's surface.

The planet is so close to its host star that it completes its orbit in around two days. It is also tidally locked, meaning the same side always faces the star. This allows surface temperatures

on the dayside of the planet to soar to over 2,500°C. The researchers believe the atmosphere is made up of corundum, a mineral involved in the formation of rubies and sapphires, as it has a very similar boiling point.

"We expect clouds to form on the cold nightside of the planet, but they would evaporate quickly on the hot dayside," said researcher David Armstrong, a member of the university's Astrophysics Group. "These results show that strong winds circle the planet, transporting clouds from the nightside to the dayside. The winds change speed dramatically, leading to huge cloud formations building up then dying away. This is the first detection of weather on a gas giant planet outside our own Solar System."

ROBOTICS

ROBOT GIVEN THE HUMAN TOUCH

Artificial hands with an almost human-like sense of touch could be on their way.

Although some modern robots do have ‘fingers’ and are able to pick up delicate objects, they usually rely on cameras and proximity sensors to determine where an object is – the robot doesn’t actually ‘feel’ anything. Now, a team at Cornell University’s Organic Robotics Lab has managed to give a soft prosthetic hand a refined sense of touch. The robot was so sensitive that it could identify which tomato out of a group of three was the ripest, simply by pressing its finger onto the surface of each piece of fruit.

To give the robot a sense of ‘touch’, the team embedded an LED light source and a system of stretchable optical waveguides – structures that steer waves of light in a particular direction – below the surface of the robot’s ‘skin’. When

nothing is being touched, the waveguides steer light from the LED straight to a sensor, but when the hand comes into contact with an object, the waveguides become deformed, and hence steer less of the LED light towards the sensor.

“Most robots today have sensors on the outside of the body that detect things from the surface,” said researcher Huichan Zhao. “Our sensors are integrated within the body, so they can actually detect forces being transmitted through the thickness of the robot, a lot like we and all organisms do when we feel pain, for example.”

Optical waveguides have been used in sensing systems for years, but this new development has been made possible by advances in lithography and 3D printing, which have enabled the production of waveguides that are sufficiently small and flexible at a reasonable cost.

NATURE

BUTTOCKS ARE TO CHIMPS WHAT FACES ARE TO HUMANS

These guys definitely don't judge things at face value. Chimpanzees can recognise each other instantly simply by looking at each others' buttocks, in the same way that humans recognise each other by looking at faces.

Working at the Kyoto University Primate Research Institute in Japan, a team of researchers led by neuropsychologist Mariska Kret from the University of Leiden compared how rapidly humans could recognise faces, and how quickly chimps could recognise buttocks, compared to other objects. Their research found that while humans are better at recognising faces, chimpanzees are better at recognising buttocks.

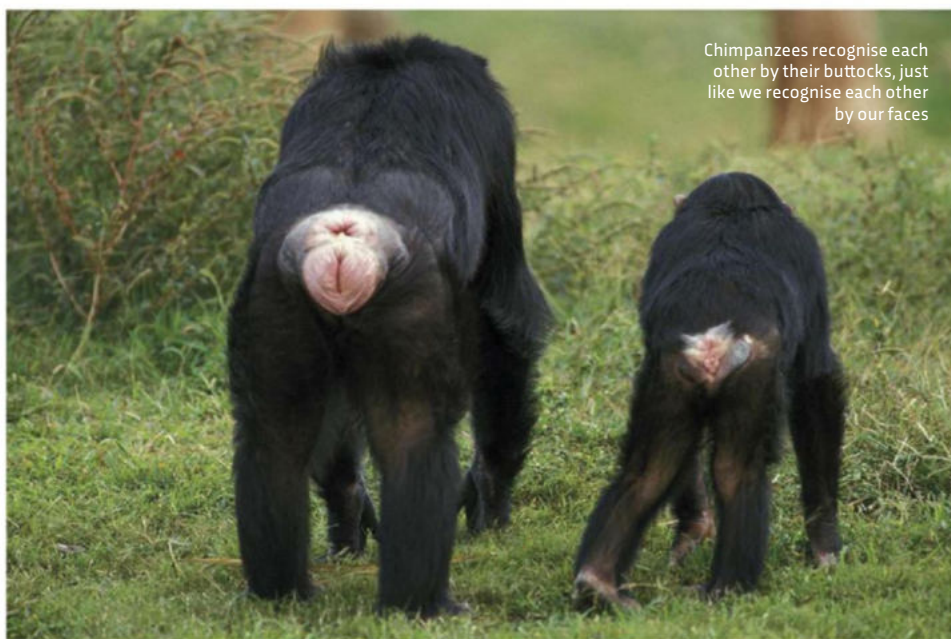
"Faces are enormously important for people, and all the features of our faces are optimally arranged to be seen and to communicate," explained Kret. "Over the course of evolution, our faces have acquired more contrast: red lips, the whites of our eyes, eyebrows and a

smooth skin that makes everything more visible."

These are all signs of good health and play a key role in sexual arousal. In chimps, however, such 'signals' tend to be found in the nether regions. "It is not without reason that it's the face and buttocks of female primates that are free of hair, which makes the skin and colour all the more visible," said Kret.

What's more, in humans the 'face inversion effect' means that faces shown upside-down are recognised more slowly, whereas inverting pictures of other objects has no effect on recognition time. The same applies to chimps and buttocks, further suggesting that chimps' brains prioritise buttocks in the same way ours prioritise faces.

As humans and chimps are so closely related, the study sheds new light on how the ways our brains process visual information may change over time as a result of evolution.



THEY DID WHAT?!



ATHLETES TOLD TO TAKE UP SWINGING

They did what?!

A group of parkour athletes were asked to swing through trees like orangutans.

What did they do?

Researchers at the University of Roehampton set up an artificial canopy imitating the high branches of trees in a jungle, and monitored the energy use of parkourists – athletes who traverse urban environments – as they jumped, climbed and swung around it.

Why did they do that?

They wanted to investigate how different approaches to moving around in trees affected apes' energy expenditure, to shed light on why some apes live on the ground and others in the trees. Doing this with real apes in the wild is difficult, so parkourists were the next best thing.

What did they find?

Climbing was found to consume the most energy. However, energy consumption when jumping and swinging varied according to branch stiffness, gap distance and the athlete's size and weight. Further research is needed to determine what makes the orangutan 'king of the swingers'...

CLIMATE CHANGE

"Species are going to lose most or all of their ranges, and a lot of them will go extinct"

Climate change is driving animals out of their natural ranges. Prof John Wiens has been studying just how bad these 'local extinctions' are becoming

How might species respond to warmer temperatures?

They could stay and change themselves: maybe spend more time in the shade, where their tolerances expand. We call that a 'niche shift'. Or they can adapt evolutionarily. But my study shows that doesn't seem to be happening. Instead they're tracking the suitable climate over space.

How does climate affect a species' geographic range?

Temperatures get cooler as you move higher in elevation, towards the top of a mountain, or higher

in latitude, towards the North or South Pole. Every single species has a sort of elevational range and a latitudinal range. We call the lowest latitudes and elevations the 'warm edge' of a range because they have the highest temperatures. That's where we expect to see species affected by climate change.

What are 'local extinctions'?

Local extinction means that in one place, all the individuals are gone. So it's not necessarily the whole species' range, but in that particular place, people can't find it anymore. Maybe 50 or 60 years ago, they looked at a bunch of species along a mountain slope and documented what species were there, then in the past 10 to 15 years they've found it's different.

So how many species have gone locally extinct?

In one or more parts of their ranges, 47 per cent out of 976 [surveyed]. The other 53 per cent were able to stay at their 'warm edges'. This is the climate change that has happened *so far* which, relative to what's expected, is actually really small. So there's been less than a 1°C increase [in average global temperature] but still there's these local extinctions across the whole planet in about half the species that anybody has looked at. It's going to



RIGHT: A lemur in Madagascar. Climate change is expected to have devastating effects on wildlife in tropical regions



ABOVE: Madagascar, one of the regions that was looked at in Prof Wiens' study

BELOW: Prof John Wiens of the University of Arizona



get worse. We think there's going to be an additional increase of between 1°C and 5°C, so I think that a lot of species are going to lose most or all of their ranges, and a lot of them will go extinct.

You found that extinction is greater in tropical zones. Why is that?

It's almost a two-fold difference. That has an intuitive explanation: in the tropics there's much less seasonality. At low elevations it's warm all year long, and at higher elevations it's cool all year long. Whereas in temperate zones, it's hot in the summer and cold in the winter. So if you're in the temperate zone, you have to be able to tolerate a broad range of conditions, and that's not so in the tropics. We think most species on Earth are in the tropics, so it's vital to note that there could be more loss of species.

Will local extinctions affect humans?

Particularly in the developing world, 50 per cent of humans' diet is coming from grasses. If you have a bad crop year, people will die. Those are places where, instead of the plants being irrigated, they depend a lot on local climatic conditions. It's very bad. It doesn't have to be extinction of the entire species, because even a local extinction will be devastating for people.



CURVY WOMEN

Researchers at the University of Oxford have found ladies with plump posteriors are healthier and more intelligent than their counterparts. The effect is due to the increased storage of Omega 3 fats, they say.

THE HAPPILY MARRIED

Forget fame and fortune – all you really need to lead a happy, fulfilling life is a loving partner. Researchers at the London School of Economics have found having a partner boosts our happiness three times more than doubling our salaries does.

GOOD MONTH

BAD MONTH

FISH AND CHIP SHOPS

Anyone for squid and chips? The increasing temperature of the North Sea is forcing cod out of UK waters, says the Centre for Environment, Fisheries and Aquaculture Science. They will be replaced by warmer water species such as squid.

EXAM CRAMMERS

It's the night before a test and you haven't done any revision. But last-minute cramming is unlikely to work. Researchers at Tufts University have found that the extra stress it causes leads to more information being lost from your memory.



COSMOLOGY

A BRIEF HISTORY OF HAWKING

This month, renowned theoretical physicist Stephen Hawking turns 75. Here's our pick of his career highlights...



1988

A Brief History Of Time is published. This exploration of space, time and black holes brings cosmology to the masses and goes on to sell more than 10 million copies.



1993

Appears in an episode of *Star Trek: The Next Generation*. The character Data plays a poker game against holographic versions of Newton, Einstein and Hawking.



1999

Voices a cartoon version of himself in an episode of *The Simpsons* 'They Saved Lisa's Brain'. It's the first of a number of appearances in *The Simpsons* and *Futurama*.



1 As a postgraduate student, Hawking began working on cosmic singularities – points in space-time that have zero volume and infinite gravitational strength, predicted to exist according to General Theory of Relativity. Inspired by Roger Penrose's theory that singularities exist at the centre of black holes, Hawking applied the same concept to the Universe, concluding that it must have started in such a singularity: the Big Bang.

2 In 1974, Hawking published a paper showing that quantum effects around black holes leads them to emit radiation (later dubbed 'Hawking Radiation'), shrink, and explode. Such radiation or explosions have never been detected, but the theoretical link he demonstrated between thermodynamics, quantum theory and gravity is still being explored, and may well be crucial to an ultimate theory of everything.



3 In 2015, Hawking claimed that stuff that falls into a black hole can escape. A debate has raged for 40 years about what happens to information about the physical state of an object that falls into a black hole. Hawking's solution is that information about objects passing into a black hole is stored in 2D form at the event horizon. It can then be emitted along with Hawking Radiation – albeit in a useless form.



PHOTOS: BIGELOW AEROSPACE



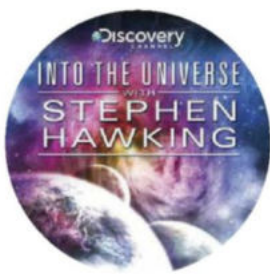
2006

Issues the first of his warnings on risks for human survival, ranging from nuclear self-destruction and being dominated by AI to alien invaders.



2010

Publication of *The Grand Design*, co-authored with Leonard Mlodinow. The writers claim to provide "answers to the ultimate questions of life".



2010

Presents a Discovery Channel three-part documentary series *Into the Universe With Stephen Hawking*. The episodes cover aliens, time travel and the Universe.



2012

An episode called 'The Hawking Excitation' marks the first of several appearances by Hawking in popular US sitcom *The Big Bang Theory*.

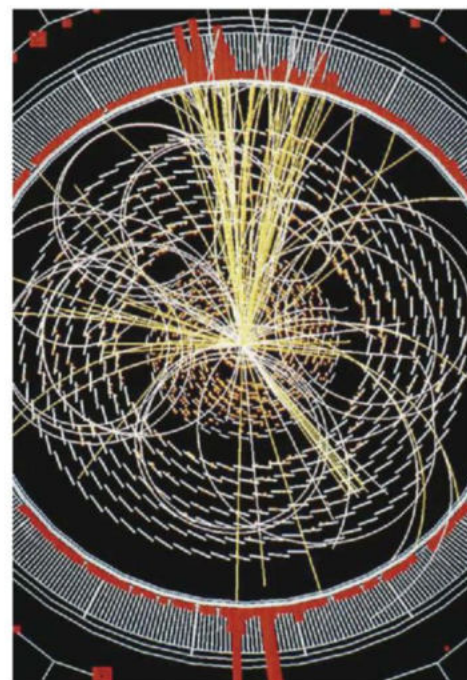


2014

Release of *The Theory Of Everything*. Based on the book *Travelling To Infinity* by Hawking's ex-wife Jane, the film stars Eddie Redmayne as the famous physicist.



4 Although less familiar to the public, Hawking has worked on aspects of quantum gravity, aiming for a so-called 'theory of everything' that unifies the incompatible theories of the very small (quantum physics) and very large (the General Theory of Relativity). His first significant work in this area in 1980 was in support of a now-dismissed theory named 'N=8 Supergravity'. Unlike other theories linked to the idea of fundamental particles having 'supersymmetric' partners, this had the advantage of only requiring four dimensions of space and time. More recently, Hawking has focused his 'theory of everything' efforts on string theory.



5 Hawking has raised many highly speculative challenges to modern physics – his openness to think differently has enabled other physicists to hone their work. So, for example, he was convinced that the Higgs boson would not be found; he suggested that time would run backwards in a collapsing universe; he said that time travel doesn't exist because we've never had visitors from the future; and argued that any information falling into a black hole is lost forever. In each case, he later changed his view – but his contribution was an inspiration for others to prove him wrong.

Amazing Images Begin with Great Lenses



ZEISS Mutar™ 0.6x Asph. T* Wide-Angle Lens
©Tophir Delancy



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INNOVATIONS

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JANUARY 2017

EDITED BY RUSSELL DEEKS



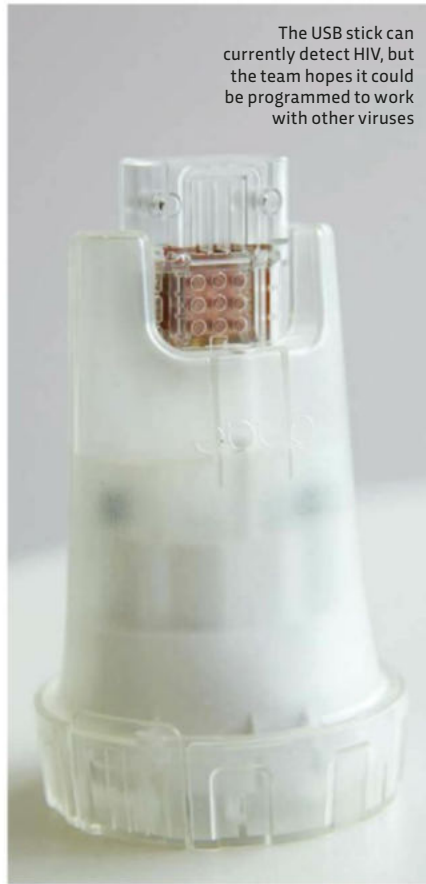
SAY HELLO TO A FUTURE STYLE ICON

Vespa unveils its new
Elettrica electric scooter

Meet the Elettrica, the brand-new electric scooter from Vespa. The Italian company is touting the scooter as “the mobility of the future”, pointing out that 60 per cent of the world’s population live in major cities and consume 80 per cent of the world’s energy. The company suggests that fuel-efficient, environmentally friendly commuter vehicles are the answer. This isn’t a new idea from Vespa, either – it has been

experimenting with hybrid engines since the 1970s.

The scooter isn’t due to go on sale until the latter half of 2017, and precise details as to its engine power, range, charging times and so on are still to be announced. As you can see, though, it lifts all of its design cues straight from the company’s classic machines of the 1960s. Rest assured, we’ll be having a ride on one as soon as is humanly possible!



The USB stick can currently detect HIV, but the team hopes it could be programmed to work with other viruses

FIGHTING HIV VIA USB

Scientists design revolutionary way to monitor disease

Scientists from Imperial College London and diagnostics technology specialists DNA Electronics have developed an HIV test that comes in the form of a USB stick. It is hoped the sticks can be mass-produced and distributed in regions where medical facilities are scarce, or could be used by HIV patients to monitor their own progress.

The device needs just a few drops of blood to detect whether the HIV virus is present, and if so at what levels. This information is then converted into an electrical signal using a mobile phone chip, producing data that can be fed into

"THE DEVICE NEEDS JUST A FEW DROPS OF BLOOD TO DETECT WHETHER THE HIV VIRUS IS PRESENT, AND AT WHAT LEVELS"

a computer or portable device running companion software (hence the USB connectivity). Results published in the journal *Scientific Reports* show that it had an accuracy rate of 95 per cent when used on nearly 1,000 samples, and could give a result in less

than half an hour – a marked improvement on most existing tests.

The study's lead author Graham Cooke said: "At the moment, testing often requires costly and complex equipment that can take a couple of days to produce a result. We have taken the job done by this equipment, which is the size of a large photocopier, and shrunk it down to a USB chip."

NEWS BYTES

UNCLE SAM NEEDS YOU!

The US Department of Defense is looking to create a better biohazard suit, and it's opened up the quest to submissions – with \$250,000 (£197,000 approx) in prizes for anyone whose ideas make it to the finished suit.



TO DODGE SNOOPERS, GO SMALL

With the Investigatory Powers Act 2016 – the 'snooper's charter' – now law, the privacy-conscious might like to note that while the Act requires larger ISPs to store users' browsing histories en masse, smaller ISPs need do so only if a request is issued.

SHOP AND GO

Amazon has opened a shop in Seattle called Amazon Go that takes 'convenience store' to a whole new level. Shoppers enter the store, then sign in via an app. As they shop, smart technology detects what items they've picked up, and keeps track of them in a virtual shopping basket. When they've finished shopping, visitors can walk straight out without queueing up. Their account is then charged for their purchases.



NO MORE 'POO BUS'

The buses fuelled by human waste that Bristol City Council unveiled while it was European Green Capital are no more, after the two bus companies involved had bids for central government funding declined.

JAPAN BUILDS SUPERCOMPUTER

Japan's National Institute of Advanced Industrial Science and Technology is building a supercomputer called ABC1. It's hoped ABC1 will achieve processing speeds of 130 petaflops, and so beat China's 93-petaflop SunwayTaihulight to become the world's fastest computer.

The Baby Boom prototype (top) has already been unveiled, paving the way for its bigger brother (below)



TRANSPORT

Plane goes boom

We're sure many readers will, like us, have experienced a pang of sadness when Concorde made its final flight in 2003. We're also kind of hoping you're over it by now... but if you're not, you'll be delighted to hear that a new supersonic jet could once more be running commercial flights by as early as 2020.

The Boom XB-1, currently being developed by aviation start-up Boom Technology, is a 44-seater airliner with a maximum speed of Mach 2.2 that would be able to fly from New York to London in just 3.5 hours – half the time it takes in a 747. The company recently unveiled a one-third scale prototype, the XB-1 Supersonic Demonstrator or 'Baby Boom', at an event at Denver's Centennial Airport.

Baby Boom uses three General Electric J85-21 non-afterburning engines, and will make its first supersonic test flights later this year. If the technology proves successful, the XB-1 proper will then go into production.

HACKING

Hacking public transport



Rail passengers in San Francisco enjoyed a weekend of free rides recently, after the Municipal Transportation Agency's ticketing system was targeted by hackers.

The hackers used ransomware to close down the system over Thanksgiving

weekend, demanding payment of 100 Bitcoins (£60,000 approx) to reinstate it. It's not clear whether any such payment was made or how the situation was resolved, but while ticket machines were out of action, passengers were able to ride the city's light railway network for nothing. It's understood that the MTA felt that allowing passengers free travel was a less disruptive measure than closing down entirely.

The attack follows other cases of ransomware being used to extort money from hospitals and schools, highlighting the need for adequate security in computer systems used to run public services.

MEDICINE

AI outperforms eye doctors

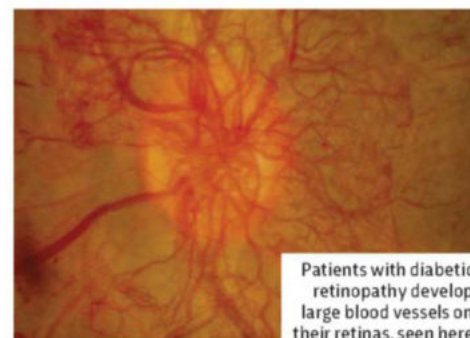
Could artificial intelligence help us detect eye disease earlier, and therefore prevent more people from going blind?

In November, the *Journal Of The American Medical Association* published its first-ever paper on 'deep learning'. The paper describes how ophthalmic researchers from various institutions, working alongside Google computer scientists, were able to teach a computer to recognise signs of diabetic retinopathy, a common cause of blindness, in patients' retinal scans.

Diabetic retinopathy affects nearly a third of diabetes sufferers, but because the condition has no symptoms in its early stages, it often goes undetected until it's too late. However, the disease *can* be treated if caught early enough, which is usually done by checking retinal scans for signs of bleeding or leakage.

The team 'trained' a computer algorithm by showing it 128,000 retinal images that had already either been diagnosed with diabetic retinopathy or given the all-clear by three ophthalmologists. It was then given another 12,000 to diagnose on its own – a task at which it "matched or outperformed" the very same experts.

A team from Google's AI division Deep Mind is said to be working with researchers from London's Moorfields Eye Hospital on using similar technology to diagnose a different eye condition.



Patients with diabetic retinopathy develop large blood vessels on their retinas, seen here

WANTED!

HELLO, VELLO

VELLO BIKE

Billed as “the lightest and most compact folding and electric bicycle in the world,” this self-charging, folding e-bike recently exceeded its Indiegogo funding target nearly five times over, and orders should start shipping in July. The Vello Bike weighs just 12kg (about the same as two portly Yorkshire terriers), folds up small enough to fit under a desk or in a suitcase, and comes with integrated front and rear LED lights. It’s available in various configurations, including a non-electric version.

\$2,390-\$3,940 (£1,895-£3,120 approx), vello.bike



CAN U FIX IT? YES U CAN!

ESSENTIAL ELECTRONICS TOOLKIT



This 23-piece toolkit from iFixit aims to take the frustration out of repairing computing and electrical goods. It contains everything you need to get inside 99 per cent of consumer electronics devices, including an array of 16 different esoteric screwdriver bits, a suction cup for removing displays, a jimmy, tweezers, picks and a heat-resistant spudger. And who can resist a heat-resistant spudger? The magnetic lid doubles as a sorting tray for all those tiny little screws, too.

£19.95 (£17 approx), ifixit.com



LIGHT MY FIRE

FLASHTORCH MINI

Made for keen campers, this frankly ludicrous torch from Wicked Lasers has a maximum output of 2,300 lumens. That’s enough light energy to start a fire... which is precisely what the torch is designed to do, although you can also drop the power to a more sensible level and just

use it as, you know, a normal torch. But where’s the fun in that?

The 219mm-long torch is built from military-grade anodised aluminium, weighs 387g, and should most definitely be kept out of the reach of children.

\$199 (£158 approx), wickedlasers.com



COMPACT CAMERA

DXO ONE

This tiny camera packs a 20.2-megapixel 1-inch sensor into a tiny aluminium body that can be used on its own, or plugged into your iPhone so you can use the Retina display as a viewfinder. It weighs just 108g, will easily fit in a jeans pocket, and has been designed for single-handed operation, yet it can shoot in RAW mode and features a six-element lens. For maximum flexibility, filters, stands and waterproof housings are available separately.

£399, dxo.com



THIS ISN'T A WIND-UP

MATRIX POWERWATCH

Matrix Industries' new smartwatch seeks to address the stupidly short battery life of such products. It does this by harnessing your body heat and converting it into electricity, which it uses to power an Ambiq Micro microprocessor that's said to be the

most energy-efficient available. Currently, the PowerWatch is limited to fitness metrics such as steps taken, sleep quality and calories burned, but later models will add email and text notifications and so on.

\$169.99 (£135 approx), matrixindustries.com

APP FEED



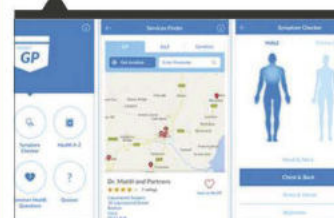
Attenborough's Story Of Life

To celebrate David Attenborough's 90th birthday, the BBC's launched this app with over 1,000 clips from his documentaries. Free, iOS/Android



Pocket GP

Powered by NHS Choices, Pocket GP lets you look up info on particular conditions, or use the Symptom Checker to convince yourself you've got a rare tropical disease. Free, iOS/Android



PhotoScan

Scan your old photos with this app that turns your device's camera into a scanner. You can crop and rotate images, and all scans are uploaded to your Google Photos account. Free, iOS/Android



FLYING HIGH

Daniel Bennett throws on his winter woollies and braves the great outdoors to put DJI's new Mavic Pro drone to the test

£1,099
dji.com

Form and function

Our first 10 minutes with the Mavic were spent simply marvelling at the thing. The gunmetal grey paint and angular chassis scream dystopian sci-fi and we like it. With the arms tucked in, under its belly and behind its back, the Mavic shrinks down to sit on the palm of your hand. The teeny footprint makes it incredibly discreet: larger drones attract crowds in seconds.

The 4K camera is mounted on a gimbal with added stabilisation. This, paired with sensors all over its shell, creates a vision system that enables it to fly autonomously. Even the remote – into which you dock a smartphone to get a live view from the drone's camera – is small but perfectly proportioned and instantly familiar to anyone who's played on games console.

Score: 10/10

Features

There are tonnes of them. Most impressive of all is the drone's 'cameraman mode', which tracks a target that you select on the screen (a car, for example). This lets you focus on the flying while the camera keeps your subject in crisp focus.

Selfie-lovers will also be pleased to know that this same vision system can be used to take your picture from the air. You simply wave at the Mavic as it flies, and the computer vision understands that you want it to lock on to your face. Then, if you want it to take a picture, you frame your face with your hands.



"The Mavic is a first for us: it's the only drone we've managed to fly without crashing"

The cameras will keep you from flying into walls, people or the ground, while the GPS will virtually fence you off from no-fly zones, like airports. There's also an auto-return button which, if you lose your way, will fly the drone back to where it launched from. As an extra you can buy VR goggles that work with the Mavic to put you in the cockpit.

Score: 10/10

Flight and filming

On a fine, still day the Mavic can reach speeds of 65km/h (40mph), which will

rapidly take it out of your field of view. Fortunately the drone will stream video to your phone – which you can livestream to the web, if you wanted – from up to 13km (8 miles) away (though we weren't brave enough to test that). There's a series of flight modes that coach you, but the Mavic is remarkably intuitive and drama-free to fly.

A flight will last 27 minutes before the batteries need recharging, fewer if it's windy, which is over in a flash. We'd suggest buying a spare battery (they cost £85 a pop) so you don't have to stop your



fun. The drone offers flowing, cinematic footage, and breathtaking stills (thanks to the aperture control), though it's perhaps not quite as good as the footage you get from a GoPro Hero.

Score: 8/10

Fun

There's little doubt that the Mavic sets the gold standard in drones. This is the first drone that's small enough to take anywhere, without compromising on image quality. Professional photographers will probably want to look

at a bigger, more powerful flyer that is better adapted to strong winds and carrying different cameras, but for anyone else the Mavic is near perfect. It's agile, easy-to-use and crammed with features.

The Mavic is a first for us: it's the only drone we've managed to fly without crashing, and it's the first that we'd like to take with us on hikes, holidays and more, just for the new perspectives it offers. If indeed there is there's a drone revolution hovering on the horizon, then this is definitely the device to kick it off.

Overall score: 9.5/10

SPECIFICATIONS

Dimensions

83 x 83 x 198mm

Camera

4k stabilised video,
12-megapixel stills, up to
120fps (720p resolution)

Mass

734g

Max speed

65km/h (40mph)

Max altitude

5km

Max flight time

27 minutes

Max flight distance

13km (8 miles)

Safety around
people and air
traffic is paramount
when piloting a drone
For a full guide, visit [drone-
safe.uk/drone-code](https://drone-safe.uk/drone-code)

REPLY

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MESSAGE OF THE MONTH

Chicken or egg?

In response to your article about scientists finding the physical root of depression, I was wondering how they were able to rule out the cause and effect issue? Significant brain changes have been observed as a consequence of brain activity – a study of London cabbies learning ‘the knowledge,’ for instance, showed that the process of learning the routes increased the size of the posterior hippocampus. They were able to show this by taking scans before and after the learning process. So how do the scientists in this instance know that the brain differences are the physical root of depression, and not a physical change as a consequence of depression?

Will Hatton, via email



London cabbies' brains are physically changed by the job

➔ It's a question of geography. Scientists are trying to find the physical markers of depression, perhaps with future treatments in mind, rather than determine what causes the differences. The reality will be a continual interplay between genetics and the environment. – **Ed**

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a pair of **Tile Slim** Bluetooth trackers. These ultra-slim trackers pair with an app and attach to your wallet or other valuables; then if the object goes missing, you can simply 'ring' it from your phone to locate it. thetileapp.com



OOPS!

The picture on pages 46 and 47 of our Xmas issue should have been credited to Ally McDowell.



What's your beef?

After reading the 'Good Month, Bad Month' section of your Xmas edition, I wondered if I had woken up in a bizarre parallel universe that morning. You appear to be reporting that fat men live longer than slim men, and that muscle-training is not directly related to strength. I have spent many hours in gyms and have noticed that people with larger muscles are consistently able to lift heavier weights. Despite this, would your advice be for me to quit the gym and the healthy diet, and to pile on a few pounds of fat?

Simon Killen, via email

➔ Thanks for your reply. You're still in this Universe I'm afraid – though if you do find yourself in a parallel one at any point, get in touch! We'd love to hear about it.

Lots of factors can have an impact on how much someone can lift, such as muscle efficiency, tendon strength, grip strength and the degree to which the nervous system is trained. There's much more to it than just muscle size. The study cited found that people who stopped weight training lost muscle mass but still maintained the strength they had built up for months after, and that lifting multiple reps of lighter weights can increase muscle size, but does not increase strength as much as lower reps of higher weights.

As for chubby dads living longer, the effect is thought to be due to a drop in testosterone following fatherhood giving the immune system a boost. – **Ed**

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Special issue



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UNSOLVED

We all know that *Brontosaurus* had a long neck and *Triceratops*

MYSTERIES

had a horned head. But there are still many things about

OF THE

prehistoric beasts that perplex the world's best palaeontologists...

DINOSAURS

WORDS: STEVE BRUSATTE



B

ack in November, I was part of a team that described a new dinosaur (pictured). Hailing from southern China and

living just a few million years before dinosaurs disappeared, the species would have looked like a deranged bird. It was about the size of a sheep and covered in feathers, with a sharp beak that it probably used to crack open nuts and shellfish. We called it *Tongtianlong* in formal scientific parlance, but gave it the nickname 'Mud Dragon' because its skeleton was found suspended in rock that hardened from ancient mud. It seems like this poor dinosaur got trapped in the muck and died. Then, some 68 million years or so later, its corpse was exhumed by dumb luck as workmen dynamited bedrock while building a school.

It's one of those things that every dinosaur-obsessed child dreams of: getting the chance to discover and name a completely new species. But I'll let you in on one of the dirty little secrets of modern

palaeontology. What my Chinese colleagues and I did wasn't that unusual. New dinosaurs are appearing everywhere these days – about 50 new species each year, an average of almost one per week. And this pace shows no signs of slowing, as parts of the world continue to open up to fossil hunters and a fresh generation of scientists, born in the *Jurassic Park* era,

come of age. Because of this bounty of new fossils, we now know more about dinosaurs than we do about many modern animals.

But that's not to say that we know everything. Palaeontology is still adventure driven by mystery, and these are some of the biggest riddles that dinosaur hunters are working on today.

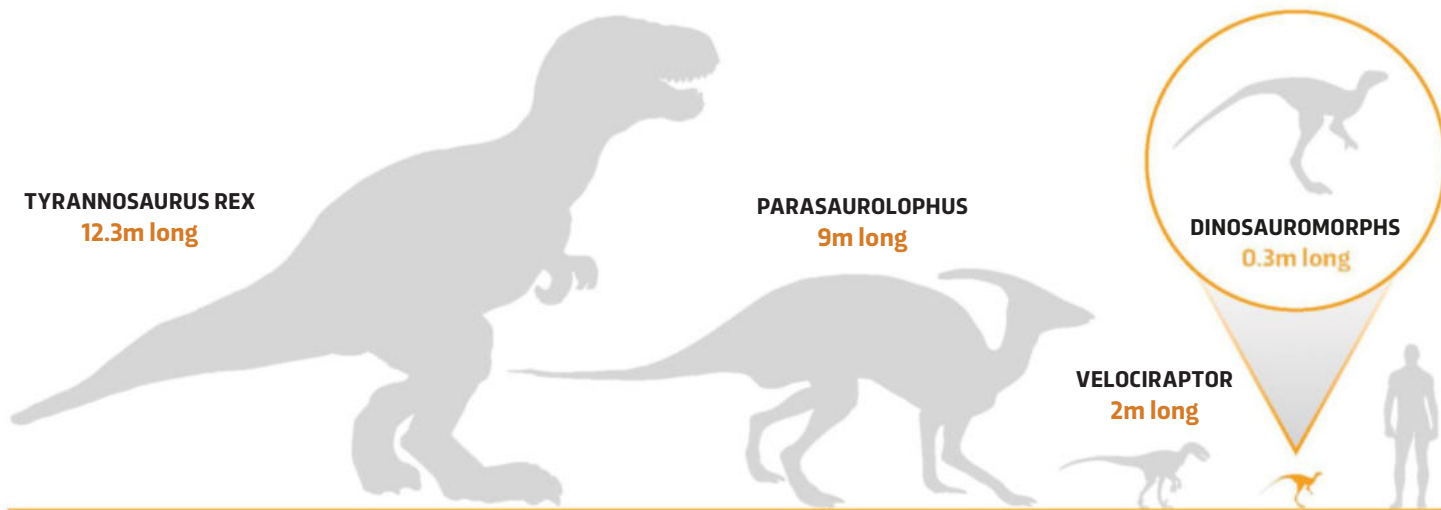


TYRANNOSAURUS REX
12.3m long

PARASAUROLOPHUS
9m long

DINOSAURMORPHS
0.3m long

VELOCIRAPTOR
2m long




WHAT WAS THE FIRST DINOSAUR?

Dinosaurs didn't start out as brutish monsters like *Tyrannosaurus* or behemoths like *Brontosaurus*. They evolved from a group of gangly, cat-sized reptiles called dinosauromorphs, which scuttled around on all-fours in fear of giant amphibians and primitive crocodile relatives called rauisuchians that lorded over the food chain. The first dinosauromorphs started leaving their tracks along the shores of Polish lakes about 250 million years ago, just 1-2 million years after the worst mass extinction in Earth history, when

perhaps up to 95 per cent of all species perished in a volcanic hellscape at the boundary between the Permian and Triassic periods.

These dinosauromorphs remained small and rare for many millions of years, then sometime after the volcanoes stopped and the world started to heal, they gave rise to the dinosaurs. The oldest dinosaur fossils come from Argentina and Brazil, and are about 231 million years old. Yet the first dinosaurs probably entered the scene earlier – maybe many millions of years earlier if some scrappy fossils from Africa turn

out to be early dinosaurs and not just very advanced dinosauromorphs with similar anatomies and behaviours. The boundary between 'dinosauromorph' and 'dinosaur' is becoming blurrier with each new discovery, but what is becoming clear is that it took tens of millions of years for these first dinosaurs to spread around the world, grow to huge sizes, and become truly dominant. More fossils will surely help, but there isn't a single Rosetta-stone type fossil that could solve the mystery of exactly how dinosaurs rose to power.



Were dinosaurs warm-blooded or cold-blooded?

The old-school image of dinosaurs was not very flattering: crack open a book from the 1950s or 1960s and you'll see drab, scaly, plodding reptiles that look like they're just waiting to go extinct.

That concept went out of favour in the 1970s, as new discoveries like the agile and shockingly bird-like *Deinonychus* proved that dinosaurs were far more dynamic and intelligent than we used to think. Some mavericks even proposed that dinosaurs were warm-blooded like modern birds: they had a constant, high body temperature that they controlled internally through their metabolism, not by basking in the sunshine like an iguana. A few decades later, the evidence is still mixed. The problem is that dinosaurs cannot be observed, so palaeontologists must rely on evidence. Some of it seems convincing: we know from studying their bones that dinos had rapid growth rates, just like modern, warm-blooded animal. But other scientists look at the same evidence and disagree, and some have proposed that dinosaurs had 'mesothermic' metabolisms, somewhere between cold-blooded reptiles and warm-blooded birds. The more we know about how dinosaurs grew, and the more chemical studies of their bones can tell us about their internal body temperatures, the more clarity we will have.

Fast, powerful dinosaurs like *Velociraptor* may have been warm-blooded

WHY DID DINOSAURS HAVE FEATHERS?

In the 1960s, the discovery of *Deinonychus* – long arms, skinny legs, head perched on an arched neck, big claws on the feet – helped solidify the theory that birds evolved from dinosaurs. In the late 1990s, the discovery of thousands of feather-covered dinosaurs in China sealed the deal. But these stunning fossils raised another question: why did feathers first develop in dinosaurs?

Feathers started out as simple, hair-like strands, which probably evolved in some of the most primitive dinosaurs as a way to keep warm. Many dinosaurs retained this basic fluffy coat, but one group of small meat-eaters modified their feathers even further. They got bigger, started to branch, flattened out, and morphed into quill pen feathers like those found on modern birds. These structures lined the arms, and sometimes the legs, forming wings. The reason that some meat-eaters elaborated their feathers was probably for display: to attract mates or intimidate rivals. But with wings, came flight...



The discovery of *Deinonychus*, pictured here, helped us establish that birds evolved from dinosaurs

DINOSAUR DIVERSITY THROUGH THE AGES

Dinosaurs owned the planet for millennia, evolving into some incredibly iconic species

HERRERASAURUS

Late Triassic

(c. 230 million years ago)

One of the very oldest dinosaurs, *Herrerasaurus* was a fierce predator about the size of a horse. It terrorised other primitive dinosaurs with its sharp claws and teeth.

STEGOSAURUS

Late Jurassic

(c. 150 million years ago)

Stegosaurus has one of the most recognisable profiles of any dinosaur. It probably used the plates on its back as display billboards, and the sharp spikes on its tail to ward off predators.

BRONTOSAURUS

Late Jurassic

(c. 150 million years ago)

The iconic 'thunder lizard', *Brontosaurus*, used its long neck to pluck leaves from high up in the canopy. It must have eaten hundreds of kilograms of plants every day, to fuel its huge body.

MICRORAPTOR

Early Cretaceous

(c. 125 million years ago)

With wings stretching out from its arms and legs, the tiny *Microaptor* looks like a strange species of bird. It is actually a dromaeosaurid, a 'raptor' dinosaur closely related to *Velociraptor*.

PARASAUROLOPHUS

Late Cretaceous

(c. 75 million years ago)

The Late Cretaceous valleys and plains of western North America would have been alive with the bellows of *Parasaurolophus*, a duck-billed dinosaur that used its gaudy head crest to make sounds.



Flight in small, winged dinosaurs might have evolved by accident

HOW DID THE DINOSAURS LEARN TO FLY?

It all has to do with the wings: no wings, no way an animal can fly. For a long time scientists assumed that wings must have evolved specifically for flight. Evolution must have driven some dinosaurs to turn their hair-like filaments into the more familiar feathers that make a wing, in order for that dinosaur to move through the air. Yet new research suggests that this probably wasn't what happened.

Wings do not show up in the first dinosaurs that started flying. Instead, wings appear in fairly large, ground-dwelling dinosaurs such as the

ostrich-like *Ornithomimosaurs* and beaked omnivores like our *Mud Dragon*. These dinosaurs were too large and cumbersome to fly. So a new theory is that wings actually originated as display structures – advertising billboards if you like – and only later were repurposed as airfoils. Flight may have evolved by accident as some of these small, winged dinosaurs began jumping between branches or leaping in the air, and suddenly found that their billboards had aerodynamic properties. It is one of the most exciting new hypotheses about dinosaurs.

TRICERATOPS Late Cretaceous

(c. 68-66 million years ago)
Triceratops is famous for its horns, with one sticking up from the nose and one from above each eye. These plant-eaters probably used their horns to wrestle rivals and attract mates.



PACHYCEPHALOSAURUS Late Cretaceous

(c. 68-66 million years ago)
Pachycephalosaurus had a thick dome of bone on the top of its head. There is debate about what this was for. Was it for display? Or did these plant-eaters butt heads in fights over mates and territory?



TYRANNOSAURUS Late Cretaceous

(c. 68-66 million years ago)
There is no mistaking the king of dinosaurs, the biggest predator to ever live on land. *T. rex* was a monster: 13m-long, with jaws so strong that it could literally crush through the bones of its prey.



Anchiornis huxleyi was a small, bird-like dinosaur that may have used its feathers to help it glide

The early bird *Vegavis*, seen here with its voice box highlighted, probably sounded similar to its modern counterparts

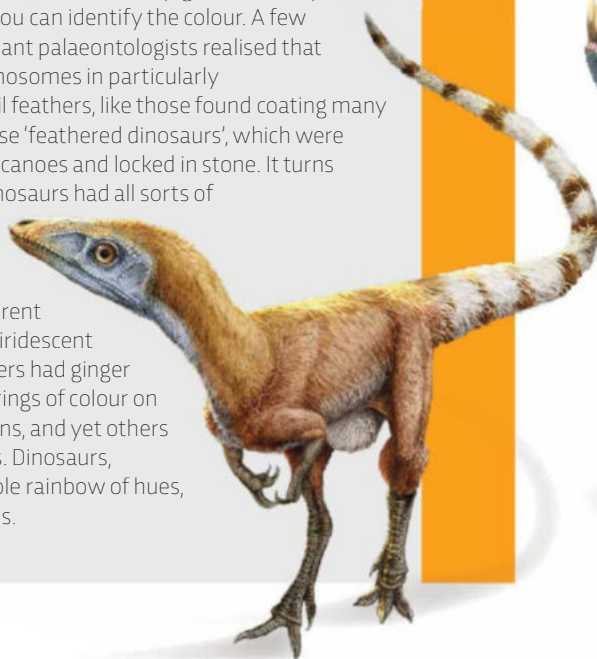


WHAT DID DINOSAURS SOUND LIKE?

In films and documentaries, dinosaurs always seem to be roaring. But we don't really know what noises they made, although there are plenty of guesses. What we do know is that some of the first birds that existed alongside dinosaurs probably sounded like today's birds. One spectacular fossil of *Vegavis* (a member of the duck/geese group of birds) includes a voice box that's almost identical to that of modern birds, even though it lived during the Cretaceous. Other scientists have attempted to recreate the sounds of duck-billed dinosaurs by scanning their skulls, building a digital model, and using software from the instrument-making industry to simulate what kind of noises these animals could make. One of these dinosaurs, *Parasaurolophus*, could have passed air through meandering chambers in its gaudy head crest. Simulations show that this air would have been emitted from the nose and mouth as a low frequency rumbling that could change in pitch. In other words, more of a bellow than a roar.

WHAT COLOUR WERE DINOSAURS?

There's something else that feathers can tell us. They unlock the potential to determine what colour dinosaurs were. If you look at modern bird feathers under a high-powered scanning electron microscope, you can see tiny blobs called melanosomes. These are little bag-like structures that hold melanin, one of the main colour-producing pigments in animals. Some melanosomes are globular, others are egg-shaped, and so on. And that's important, because different shapes hold different colour pigments. So if you can identify the shape, you can identify the colour. A few years ago some brilliant palaeontologists realised that you could find melanosomes in particularly well-preserved fossil feathers, like those found coating many of the famous Chinese 'feathered dinosaurs', which were buried rapidly by volcanoes and locked in stone. It turns out that different dinosaurs had all sorts of different melanosomes, which meant they had a variety of different colours. Some were iridescent black like crows, others had ginger feathers, some had rings of colour on their tails like raccoons, and yet others had splotchy colours. Dinosaurs, therefore, had a whole rainbow of hues, just like modern birds.



WHY DID *T. REX* HAVE SUCH TINY ARMS?


Poor *T. rex*, it's the butt of so many jokes about its tiny arms. Its body cries out Arnold Schwarzenegger, but its arms scream Woody Allen. The king of dinosaurs was a 13m-long, meat-crunching machine as an adult, but its arms were no bigger than mine. This has amused, and confused, palaeontologists for decades. But what's important to realise is that while its arms were incredibly short, they were also very muscular. So they must have been doing something. Otherwise, evolution would have just got rid

Perhaps *T. rex* did push-ups to lift itself from the ground after it slept

of them, the same way that the hindlimbs of whales disappeared when they were no longer needed. There are many ideas floating around: perhaps *T. rex* did push-ups to lift itself from the ground after it slept, or used its arms as claspers when mating, or simply braced itself against its prey while feeding, for a little extra stability. We still don't know the answer. However, exciting developments in cutting-edge computer modelling software could help us come up with a solution before too long.




No wonder *T. rex* was angry: he couldn't even scratch his belly!



WHY DID DINOSAURS DIE OUT?

And we end with the most enduring mystery of all, the one that has been bickered about ever since the first fossils of giant, extinct reptiles were found in England in the 1820s. Why aren't dinosaurs around today?

Of course, we now know that birds evolved from dinosaurs, so some dinosaurs do persist, but the spirit of the question remains. There is nothing like a *T. rex*, *Triceratops*, or *Brontosaurus* in today's world. They dominated the planet for over 150 million years, but suddenly disappeared from the fossil record 66 million years ago, at the end of the Cretaceous. That's exactly the same time that a 10km-wide asteroid struck what is now Mexico, impacting with the force of over a billion Hiroshima bombs and unleashing an instantaneous apocalypse of earthquakes, tidal waves, wildfires, and hurricane-force winds.

Although palaeontologists still like to argue about what role the asteroid played in the dinosaur extinction, there really isn't much of a mystery left. The asteroid did it, and did it quickly. There are few signs that dinosaurs were struggling before that one fateful moment, when the course of prehistory was changed forever. No dinosaurs, save a few birds, were able to endure the devastation. But some small, omnivorous, furry mammals did. These plucky survivors found themselves in an empty world, and as the planet started to mend, they rapidly evolved into all sorts of new creatures, including the first primates. It was in the ashes of the dinosaurs that our ancestors began their long march. 

PHOTOS: GETTY X2, SCIENCE PHOTO LIBRARY, NICOLE FULLER/SAVO ART/UT AUSTIN



Dr Steve Brusatte is a palaeontologist at the University of Edinburgh and the author of many books on dinosaurs. He is currently writing *The Rise And Fall Of The Dinosaurs*, to be published in 2018.

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Inside the **TEENAGE MIND**

It wasn't fair and it wasn't your fault. Neuroscientists are discovering just how hard it is to be a teenager

Words: **Andy Ridgway**



RIGHT: Teenagers are more likely to carry out risky behaviour than adults

BELOW RIGHT: Prof Frances Jensen says it is mismatches in the adolescent brain that cause stereotypical adolescent behaviour

“Teenagers are running with a lot of emotional energy, without the frontal lobe being able to dampen this down as it does in an adult”

T

eenager. This is a word that’s become synonymous with a certain attitude and way of life. Mood swings.

Rudeness. Risk-taking. Late nights and long lie-ins. It’s fair to say that 13-19-year-olds have something of a PR problem.

Many of the personality traits we associate with teenagers have become a bit of a lazy shorthand over the years, but there’s no doubt that there is some truth to their reputation. For starters, when compared to childhood, the adolescent years are associated with a whacking great 200 per cent hike in the number of deaths from preventable causes. Something is clearly going on.

But the more we learn about the teenage brain, thanks particularly to advances in neuroimaging over the past decade, the more we’re realising that much of typical teen behaviour is the result of the unique way their brains are wired. In other words, they’re at the mercy of their neurons.

What’s more, researchers are unlocking some surprising abilities in teenagers – abilities that are often hidden from view. Who knew, for instance, that teenagers are *better* at weighing up the risks and benefits of certain activities than adults in some circumstances. Or that teenagers actually get a kick out of

learning and have an opportunity to supercharge their IQ?

RISKY BEHAVIOUR

If there’s one part of the brain that’s most responsible for teenage behaviour, it’s the limbic system. Deep within the brain, behind the ears, this collection of structures generates emotion and the feelings of reward we get when we do something enjoyable. It develops rapidly at puberty, which typically takes place between the ages of 10 and 12. During this time, axons – the long, slender projections present on a nerve cell – become





coated in a fatty sheath called myelin. This coating allows a neuron to transmit its impulses more rapidly, giving the limbic system a boost.

At the same time, the prefrontal cortex is the last structure in the brain to develop fully. In fact, it's not fully formed until we're in our twenties. This region, at the top of the head and lying within the frontal lobe, is where we imagine what might happen if certain scenarios play out. We then put these mental processes to use when we're navigating complex social situations. It's not that it's completely ineffective in the teenage brain, it's just not as effective as it will be.

This slow development of the prefrontal cortex, and the fast development of the limbic system, leads to a mismatch in the teen brain. "The limbic system controls sexual behaviour, novelty seeking, reward and iction," says Prof Frances Jensen at the iversity of Pennsylvania and author of *The* . "That's what gets connected rst. So teenagers are running with a lot of otional energy, without the frontal lobe ing able to dampen this down as it does in

Back in 2013, Dr Adriana Galván, a neuroscientist and developmental psychologist at the University of California, Los Angeles, decided to explore risk-taking

behaviour of adolescents in some detail. She invited a group of adults and teenagers to take part in a gambling activity. They had to decide whether to accept a gamble involving a 'spinner' which had the **amount they would** lose on one side and the **amount they would** win on the other.

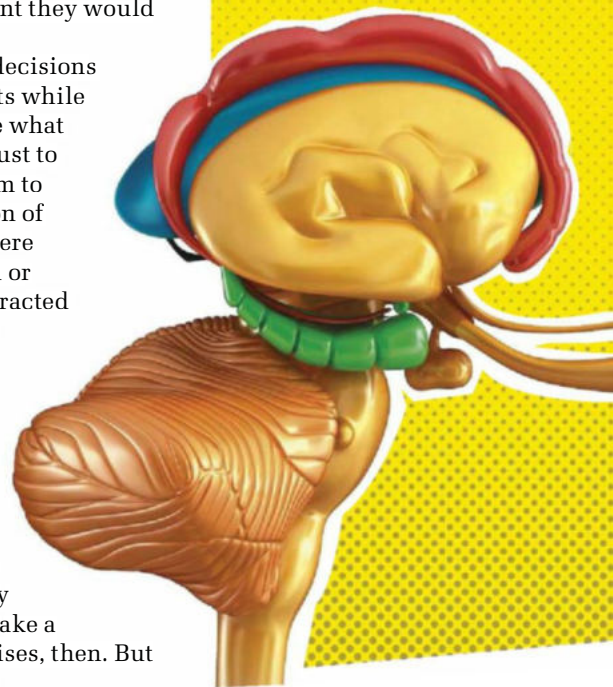
They were invited to make decisions with various win/loss amounts while lying in an MRI scanner to see what was going on in their brains. Just to add an extra element of realism to the setup – and an extra frisson of excitement – the volunteers were told that the amount they **won** or **lost** would be added to or **subtracted** from their payment for **taking** part in the study.

One thing shone through in the brain scans: the teenagers showed more activity than the adults in their ventral striatum, a region associated with the limbic system and the brain's reward circuitry. It meant **they** were more likely to gamble – take a risk, in other words. No **surprises**, then. But it didn't end there.

Sometimes, particularly when larger sums of money were on offer, ●

ABOVE: Improvements in scanners have allowed neuroscientists like Dr Adriana Galván to decipher teenage brains

BELOW: The brain's limbic system is responsible for the behaviour of teenagers



ANATOMY OF AN ADOLESCENT BRAIN

Climb inside the unique mind of a teenager

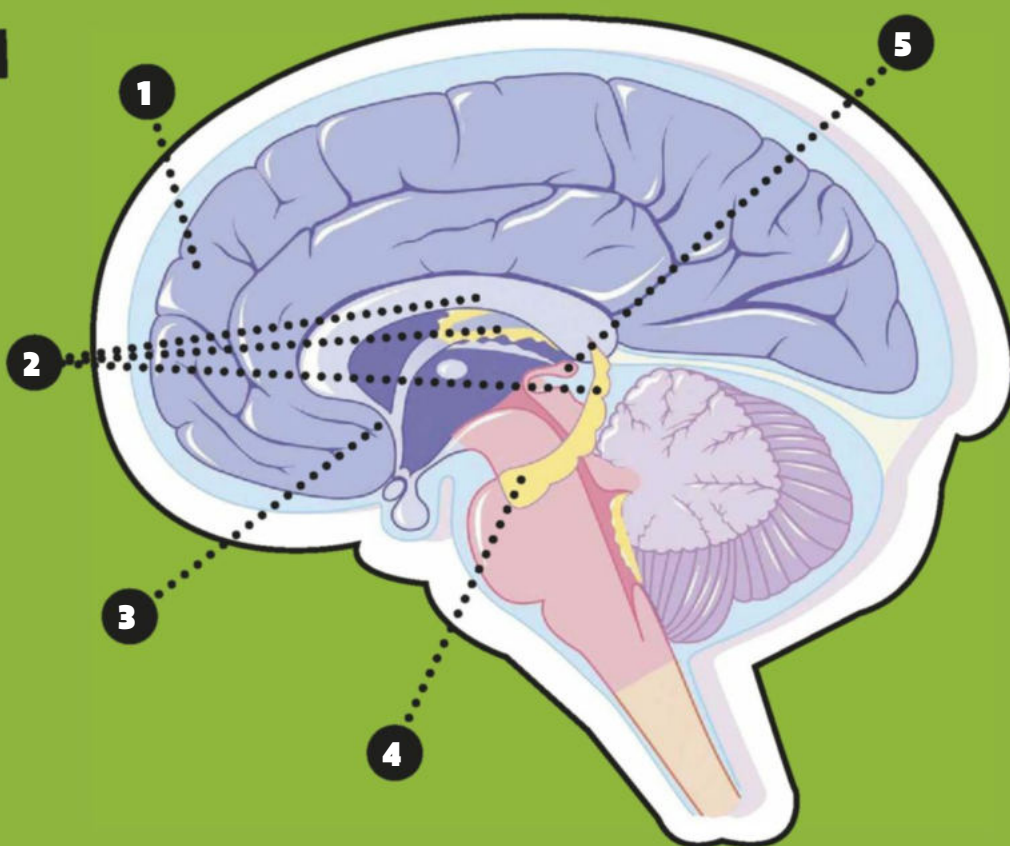
1 Prefrontal cortex: involved in planning, decision-making and stamping out any urges to do something inappropriate at a party. It's present in the teenager, though not yet fully functional.

2 Limbic system: if the brain has a 'teen region', it's here. Regardless of age, we all have one – it's just given more of a free rein in a teenager.

3 Nucleus accumbens: this focal point in the reward system is activated by activities we find pleasurable, from eating food and having sex to seeing Facebook likes.

4 Hippocampus: this plays an important role in memory and learning, and has strong links to the reward centre in teens.

5 Pineal gland: a major source of melatonin, the late release of which is responsible for teenagers' late nights and long lie-ins.



● teenagers were more likely to accept the gamble than adults – and it's a decision that won them more cash. In short, their risk judgment was better. "The world is full of uncertain outcomes," says Galván. "This research suggests that adults may be more cautious in circumstances where they needn't be." This has implications for the wider world, says Galván. "Being cautious can preclude learning something new. Anecdotally, teenagers are more likely to join a new team or approach a new social group than adults."

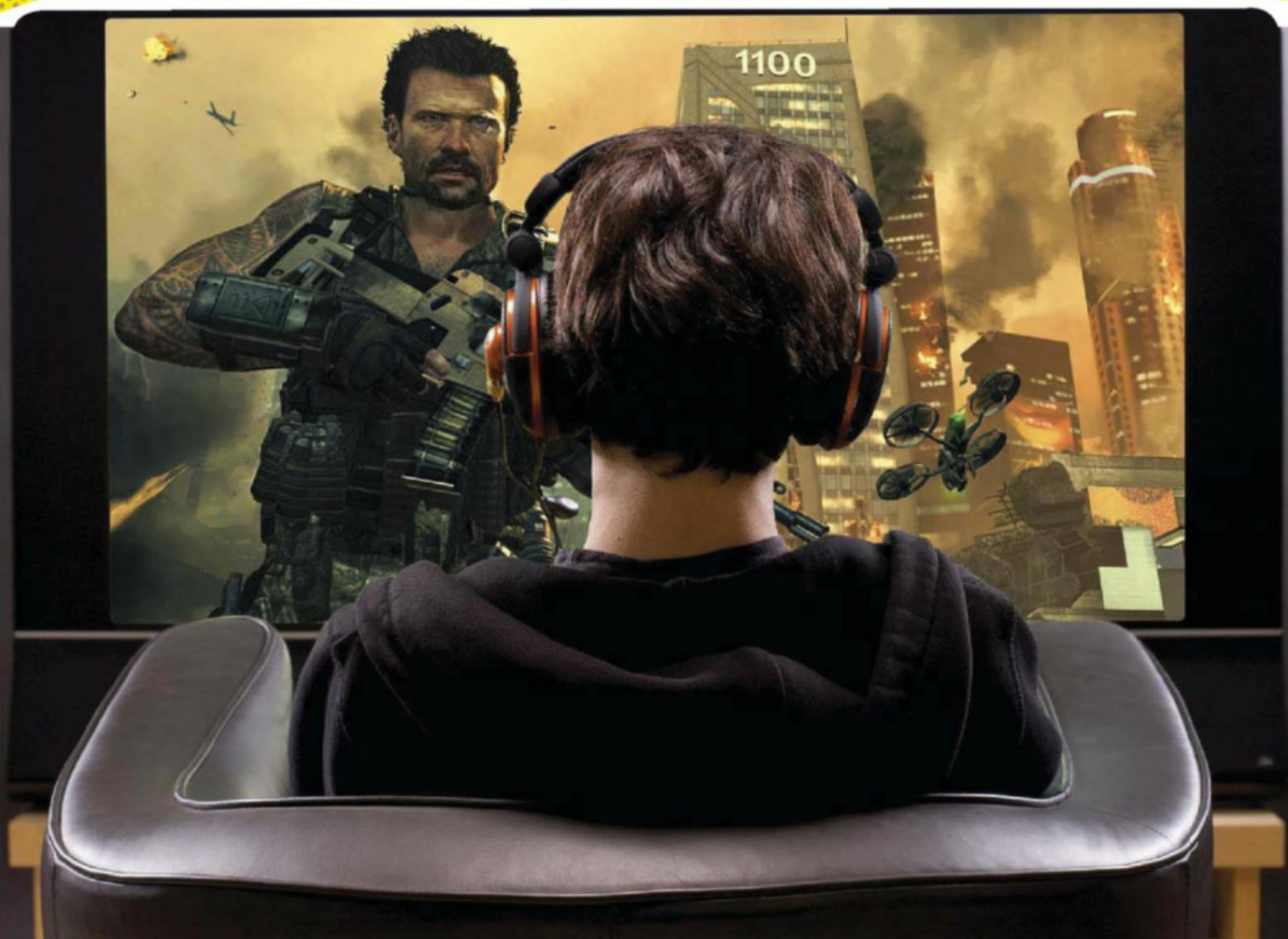
This limbic-driven tendency to seek out new thrills is an important part of growing up, says Yale University psychologist Dr BJ Casey. "I think we have evolved in such a way that there are changes in the [adolescent] brain that pull the teenager out of the safety of their home," she explains. "The only way they are going to learn to regulate their emotions, actions and desires is if they are put in situations where they have to do that for themselves."

But this taste for thrill-seeking and risk-taking is what's thought to be at least partly responsible for the greater rate of preventable deaths among teenagers. It's

perhaps telling that in the gambling study, when the teenagers were making the better risk-taking decisions than adults, they did not take any longer to make the choices than at other times. Rather than being calculated, measured decisions, they were more spontaneous – and just happened to be the right choice. Sometimes of course, it's a tactic that can have fatal consequences.

LIVE AND LEARN

It's not just risk-taking that gets a teenager's reward centre fired up. Research published earlier this year, led by Dr Lauren Sherman while she was at the University of California, Los Angeles, provided an insight into why teenagers spend so much time on social media. When she and her colleagues showed a bunch of 13-18-year-olds photos that had a large number of 'likes', it generated a big response in their reward centres. "It's probably something we could have figured out just by asking teenagers, without going into the scanner," says Sherman, now a researcher at Temple University in Philadelphia. "What's interesting to me, though, is that this circuitry is involved in motivating future behaviour."



Perhaps more surprising is what happens in the teenage brain when they are learning. In research recently published in *Neuron*, Galván found that teenagers performed better than adults at a computer task that involved learning by trial and error which of two CGI flowers a CGI butterfly preferred. “This was interesting because the hippocampus, the main learning centre in the brain, was more responsive during the learning process,” says Galván. “The teenagers’ brains showed greater communication between the hippocampus and the reward system compared to the adults, and that’s what helped them learn better.”

Given that the teenage brains associated learning with reward, it raises the question of why they’re often accused of a less than enthusiastic attitude towards homework and revision. It may simply be that although learning *does* prompt a larger reaction in their highly reactive reward centres than it does in adults, there are still other things, like playing computer games, that get their reward systems even more revved up.

There’s also the issue of sleep, or more specifically the lack of it with many teenagers, that’s inextricably linked to the

“Teenagers are more likely to join a new team or approach a new social group than adults”

ability to learn. It seems that not getting enough shut-eye is not necessarily the teenager’s fault – it turns out that they produce melatonin, the hormone that helps us to sleep, much later than adults. The oft-quoted time delay is 1am rather than 10pm, and it can be a source of frustration for teens trying to get a good night’s rest.

But issues of sleep and motivation aside, the teenage years are still a prime time for learning. Not only does it send their reward centres into a frenzy, but adolescence is also the time when certain synapses – the connections between nerve cells – are lost if they aren’t used, while others are strengthened. “When you learn, a synapse is getting bigger and stronger,” says Jensen. ●

ABOVE: Teenage brains are wired to associate learning with reward... but they may get more of a high from gaming than reading

A TEENAGER'S SURVIVAL GUIDE

BEING HASSLED BY YOUR PARENTS?
HERE ARE SOME SCIENTIFIC RIPOSTES...

**YOU NEVER
STOP LOOKING
AT YOUR
PHONE!**

If you had a brain like mine, you'd be checking Facebook just as much! Each time someone likes a photo I'm in, my nucleus accumbens goes into meltdown and that just makes me want to post more photos and see how many times they've been liked.

**YOU'VE EATEN
EVERYTHING IN
OUR FRIDGE!**

Evolution has primed me to leave the sanctuary of the family home and seek out new things that provide me with learning experiences. So you won't have to worry about the contents of your fridge much longer. But you will have to worry about where I spent the night...

**GET ON WITH
YOUR
HOMEWORK!**

I'm completely at the whim of my limbic system. While a spot of algebra does set my reward centre jangling, it pales into comparison with what happens to it during a three-hour stint of Call Of Duty. So Call Of Duty it is.

**ALL YOU DO
IS GRUNT!**

Okay, so my prefrontal cortex is still a work in progress. Once it's firing on all cylinders, I'll be happy to engage in conversation about the world's affairs with all the charm and wit of Stephen Fry. In the meantime, I'll stick with a grunt, thanks.

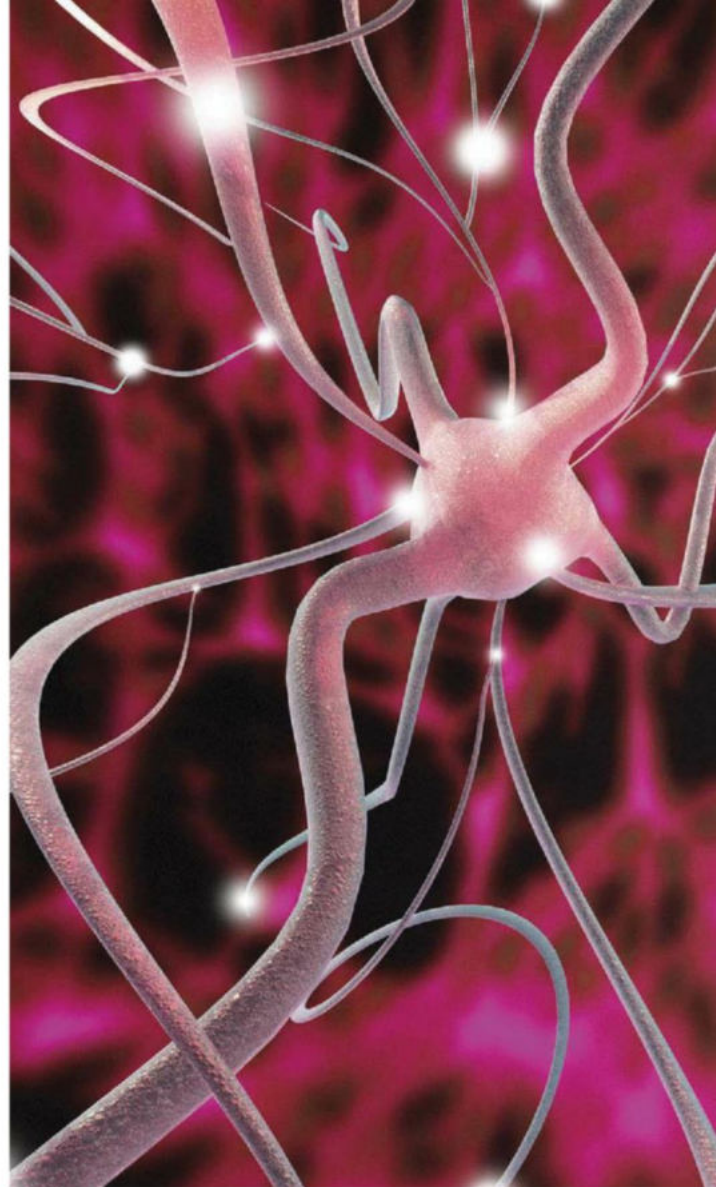
**YOU NEVER
GET OUT
OF BED!**

Don't blame me, blame my melatonin. I was waiting until at least midnight for it to kick in last night and then I finally got off to sleep. So I need a lie-in to make sure I get the 8-10 hours of shut-eye I require.

**PLUS A COUPLE OF 'CATCH-ALL' RESPONSES
FOR THOSE AWKWARD MOMENTS...**

"Sorry I can't help out, I'm busy pruning my synapses."

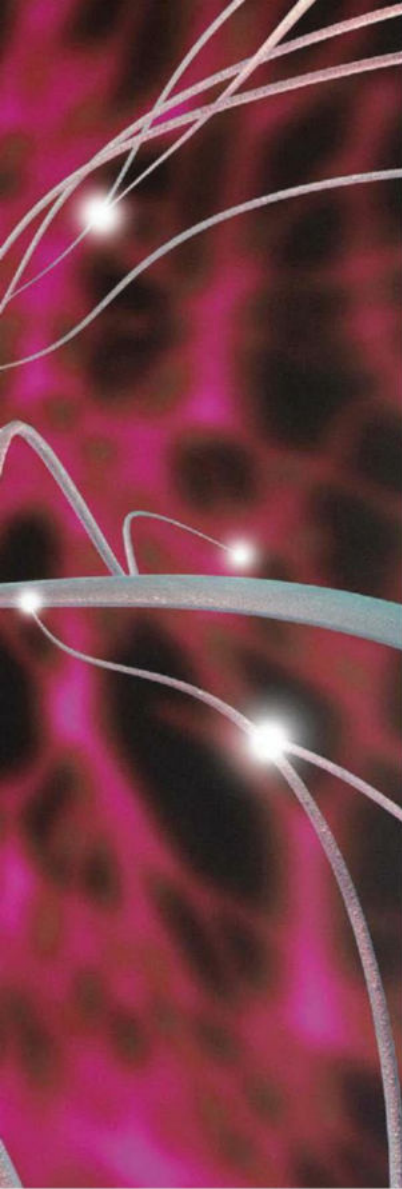
"It wasn't me, my limbic system made me do it."



PHOTOS: GETTY X2

• An unprecedented view of the changes that take place in teenage brains is currently being provided by the U-Change initiative, a collaboration between University College London and the University of Cambridge that's funded by £5.4m from the Wellcome Trust. While previous studies have examined the teenage brain at one moment in time to provide a snapshot of its structure, U-Change will be probing the brains of 2,400 British teenagers over a three-year period.

Already, the study has shown that the cerebral cortex in 14-24-year-olds appears to become thinner over time. At the same time, the myelin around nerve fibres in the cortex increases. A small proportion of the thinning in the cortex is down to the pruning of synapses, as little-used links between neurons are lost. But most of the shrinkage is something of an illusion, caused by the increase in the fatty myelin. "If you dipped a piece of paper in fat, the edge that you dipped into the fat would look translucent – the paper would almost look like it had shrunk,"



ABOVE LEFT: Axons, the long projections on nerve cells, become coated in myelin during puberty, which allows impulses to travel faster

ABOVE RIGHT: Everyone is on their own journey, so some teenagers are ready for activities like travelling and driving earlier than others



says Cambridge University's Prof Peter Jones, a principal investigator on U-Change. "That's analogous to what's happening here."


Crucially, this increased myelination happens most in the cortex's major 'hubs'. It's thought that these connections may be important for the 'top-down' control by the cortex of the limbic region – the part of the brain that's the seat of risk-taking and rash, emotional decisions. It's something the researchers plan to investigate.

With all of the changes that take place inside the teenage brain, though, there is unlikely to be a one-size-fits-all timetable for neurological change that every single adolescent will conform to. "Everyone is on their own individual journey," explains Jensen. And it's something that should be acknowledged more in future, she says. "At some point I think we need to have something like an app to show you where you are in terms of your brain's ability to learn and your brain's ability to make decisions with the frontal lobe."

It leads to the prospect of different people being allowed to start engaging in certain activities, such as driving or buying alcoholic drinks, at different ages. "Society makes it very confusing in terms of when we're allowed to do certain things," says Jensen. "It may be that we could have personal boundaries, so not everyone is allowed to do something at 18 – someone may get to that point at 17 and others at 21." In other words, your 'brain age' would determine what you can do and when, rather than the number of birthdays you've had. 📍

Andy Ridgway is a science journalist and a science communications lecturer at the University of the West of England.

DISCOVER MORE

 **4** Listen to episodes of *All In The Mind*, which explore the limits and potential of the human brain at bbc.in/2gqOijr

WHO WANTS TO LIVE FOREVER?

A new facility
will store tens
of thousands of
cryogenically
frozen people
The hope is to
one day bring
them back to life, but
just how realistic
are its aims?

WORDS: Tom Ireland

For centuries, the world's physicists, writers and philosophers have argued over whether time travel is possible, with most coming to the conclusion that it's never going to happen. But on an 800-acre plot of land just outside the small town of Comfort, Texas, a group of architects, engineers and scientists are building a 'Timeship' that they say could transport tens of thousands of individuals to a far-distant future.

Their approach does not involve the use of flux capacitors, or zooming at light-speed through black holes. Instead, the Timeship aims to store people at such low temperatures that their bodies are preserved for a future civilisation to reanimate them, a concept known as cryonics. "Just as a spaceship allows people to move through space, Timeship will allow people to travel to another time in the future," explains Stephen Valentine, who is the director and principal architect of the Timeship project. ●



PHOTO: GETTY



“CRYONICS IS UNIQUE IN THAT IT IS UTTERLY RELIANT ON TECHNOLOGY THAT DOES NOT EXIST YET”

Valentine has been given a multimillion-dollar budget from anonymous donors to develop a ‘Mecca’ for cryonics and life extension. As well as a fortress-like building that can store frozen people, Timeship plans to store other precious biological samples such as organs, stem cells, embryos, and even the DNA of rare or threatened species. The site will also house the world’s largest life extension research centre, the Stasis Research Park.

The entire facility will be off-grid, using wind and solar energy to avoid potential power outages, and the location has been carefully chosen to be far from earthquakes, tornadoes, snowstorms and any other turmoil the world might throw at it in the next few hundred years. “You don’t want to be near a military base or nuclear plant either,” says Valentine, who speaks at a frantic pace with a theatrical Boston drawl. He has spent five years finding and designing the site, while studying pyramids, ancient tombs, bank vaults and medieval fortresses – “anything that has stood the test of time.” He has even consulted experts on how to protect frozen time-travellers from the effects of a nearby two-megaton nuclear bomb.

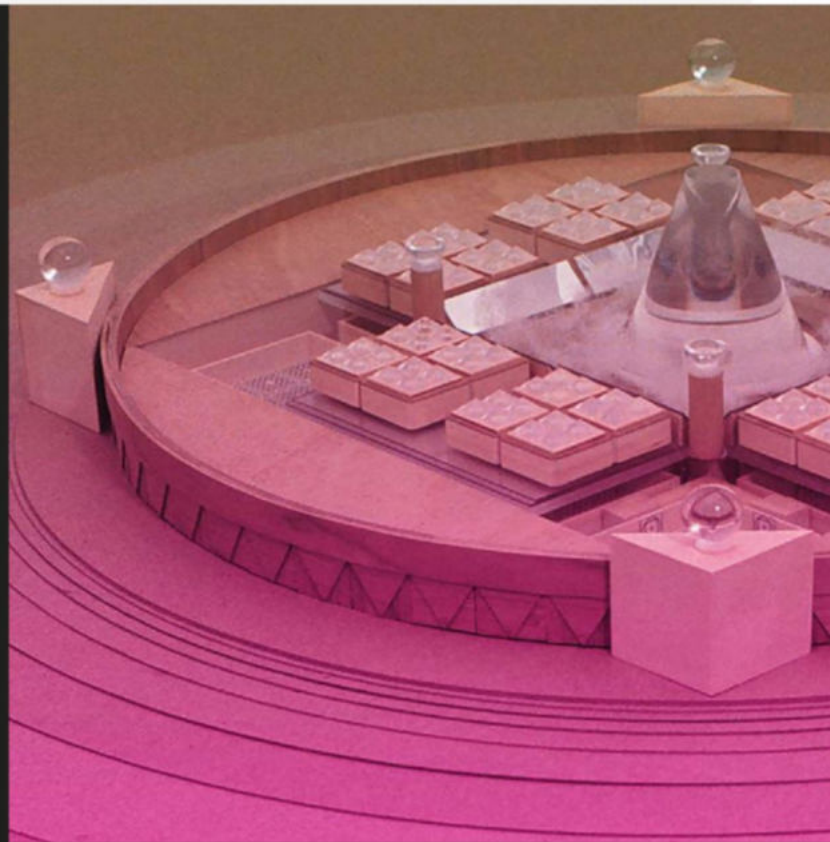
The resulting design is an epic spaceship-castle hybrid, with thick, low, circular walls surrounding a central tomb-like chamber, where thousands of storage pods will be held under high security. The exact technique that will be used to cool the bodies is not yet clear, but it is likely to involve the bodily fluids being drained and replaced with a solution that helps protect tissue from the formation of ice crystals. The storage pods will use the cooling power of liquid nitrogen to keep the bodies at around -130°C , and should be able to maintain low temperatures without power or human maintenance for up to six months, says Valentine. He hopes to start testing the first prototype pods next year.

CHILLED TO PERFECTION

The idea of freezing people in the hope of reawakening them is not new. Fifty years ago this month, James Bedford became the first person to be cryogenically frozen, and his body remains in cold storage to this day. Various organisations and companies have offered similar services over the past decades, often using hopelessly crude freezing techniques or failing to store the bodies properly.

Today, the cryogenic freezing of human stem cells, sperm, eggs, embryos and other small tissue samples is a routine part of scientific research and reproductive medicine in many countries. Vitrication, a process that turns samples into a glass-like state rather than ice, was developed in the early 2000s as a way of overcoming the problems of ice formation in and around cells. Ice formation is an issue because it can cause dramatic differences

This concept shows how Timeship might look. The inner region is used for liquid nitrogen storage. The eight square-shaped structures house hundreds of frozen patients

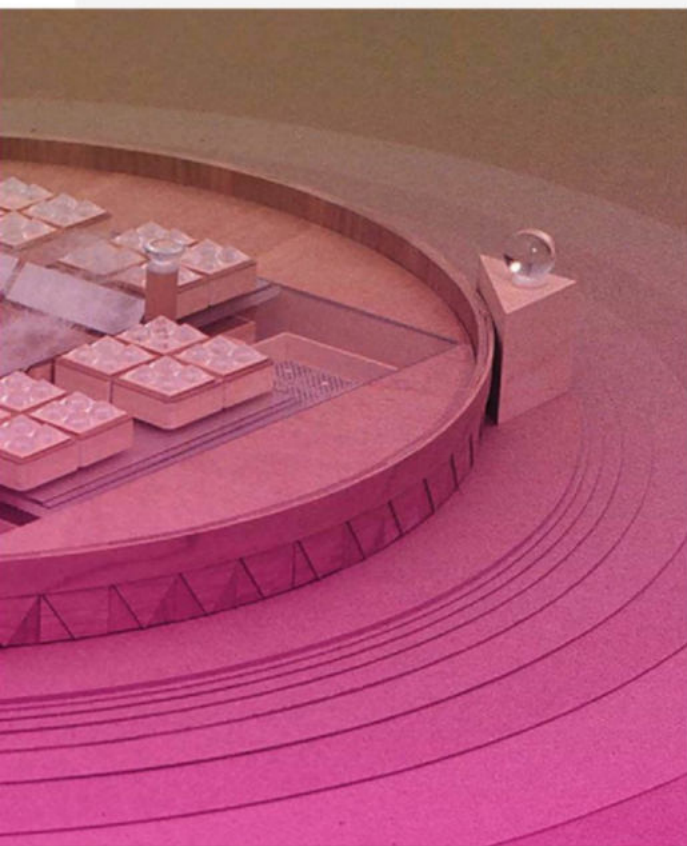


No one would tell us what these pods are used for...

in concentration inside and outside the cell, sucking water out and destroying it. In late 2002 and early 2003, a team led by vitrification pioneer Gregory Fahy used a cocktail of antifreezes and chemicals to cryopreserve a whole rabbit kidney. The organ appeared to function normally after it was thawed and transplanted back into its donor.

Several other breakthroughs have encouraged Valentine, and the wealthy entrepreneurs backing Timeship, that freezing a person properly is now feasible. In 2015, a team from the company 21st Century Medicine claimed to have developed a new vitrification technique that preserved pig and rabbit brains without any visible damage. That same year, scientists from Alcor, a company associated with Timeship, found that when microscopic worms were deep-frozen and thawed, they not only survived but could 'remember' associations they had learnt before they were frozen.

For Valentine and the cryonics community, these studies are proof that if the most advanced scientific techniques are used, then human organs, brains, and even memories and personalities could survive being frozen. However, cryonics is unique in that it is utterly reliant on technology that does not exist yet. Even if so-called 'patients' are frozen perfectly after death, they are simply guessing that scientists will one day be able to reanimate them and cure their illnesses – and will want to. ►



1

FIVE MORE WAYS TO CHEAT DEATH

Don't fancy freezing yourself? Here are some alternative ways to prolong your life...

1 UPLOAD YOUR MIND TO A COMPUTER

Some believe that we may one day be able to recreate every detail of our brains on powerful computers, enabling our thoughts and experiences to live on without physical bodies. However, neuroscientists still struggle to simulate the workings of the most primitive animal brains, so it remains a distant prospect.



2



3

2 HIBERNATE

Doctors sometimes lower the body temperature of patients dying from severe injuries to buy more time while they perform emergency surgery. Lowering the body's temperature from 37°C to around 10°C slows down all biological processes, resulting in a kind of 'induced hibernation'. A similar technique has been proposed as a way of putting long-distance astronauts into a deep sleep.



4



5

3 BUILD YOUR OWN BODY

Human tissue such as cartilage and even

simple organs, such as bladders, can now be grown in a lab using a patient's own cells and special 3D printers. If the technology continues to develop, doctors may be able to grow new body parts to replace diseased or worn out ones.

4 BECOME A VAMPIRE

After research in mice showed that the blood of young animals helped old animals' memory, endurance and tissue repair, trials have begun to see if blood transfusions from young people can reduce or reverse ageing in older humans, too. Scientists hope to identify the blood-borne chemical components of ageing.

5 TIME TRAVEL

If it was possible for a person to travel at very close to the speed of light, then time would slow down for them relative to everyone else. This means that when they return to Earth, thousands of years may have flown by. Unlike in *Back To The Future*, there would be no way back to the past.

● Prof Brian Grout, chairman of the Society for Low-Temperature Biology, says that cryonics has become more credible in recent years, and that it would be “wrong to dismiss the idea of whole-body freezing.” But he does have one big problem with the central idea of the Timeship mission: the preservation of dead bodies.

“The biggest difficulty is not whether it is possible to recover a whole person from ultra-low temperatures – there is a reasonable chance that will happen in the future. It is the fact that they will be dead. If they were dead when they were frozen, they will still very much be dead when you thaw them out.”

FROZEN IN TIME

Freezing people alive could mean they can be placed in suspended animation for, say, long-term space flights, says Grout. Technology that may be able to cure what are now incurable illnesses is also not hard to imagine, he says, but overcoming death is another matter. “The technology they will need is not cryotechnology, it’s reversing death. That’s a pretty big leap for me.”

Valentine refuses to be drawn into a debate on whether Timeship would accept living patients if the authorities allowed such a thing, saying that it is a matter for the medical and legal professions. But he and others believe that various technologies such as gene editing and nanotechnology could one day change how we perceive death, and reverse it.

“THE TECHNOLOGY THEY WILL NEED IS NOT CRYOTECHNOLOGY, IT’S REVERSING DEATH. THAT’S A BIG LEAP”

Other futurists believe that it may one day be possible to upload our minds onto a computer, freeing humanity from the restraints of a physical form entirely.

Banking on these future technologies may seem like a pretty big gamble, especially when the costs of cryonic preservation start at around \$30,000. Yet for people whose lives are cut short by illness, a miraculous breakthrough may literally be the only hope they have. An example is the 14-year-old British girl who recently made headlines around the world after writing, before she died of cancer, that she wanted to be frozen. A judge ruled that her wishes must be respected, and her body was sent to the US to be frozen. She wrote: “I’m only 14 years old and I

1940s

French biologist Jean Rostand studies how extremely low temperatures affect the properties of materials and living things – now known as cryogenics.

1962

Inspired by Rostand’s work and science fiction, a physics teacher and war veteran called Robert Ettinger publishes *The Prospect Of Immortality*, proposing that humans could be frozen and awoken in the future.

1965

As societies and companies dedicated to life extension start to form across the US, the term ‘cryonics’ is coined for the movement started by Ettinger.

1967

Prof James Bedford is the first person to be frozen. In 1991, when removed from storage to be evaluated, his body is found to be preserved but damaged, with discoloured skin and “frozen blood issuing from his mouth and nose”.

1979

Nine supposedly frozen patients are found decomposing in the ‘Chatsworth crypt’ in Los Angeles. In the 1960s and 1970s, cryonics pioneers struggle to maintain the temperature of their frozen patients. Bedford is the only person frozen in this era who remains frozen today.

A BRIEF HISTORY OF CRYONICS

don't want to die, but I know I am going to. I think being cryopreserved gives me a chance to be cured and woken up, even in hundreds of years' time."

BREAKING THE ICE

What the world will look like in hundreds of years' time is anyone's guess, but there are many logistical challenges for anyone is woken from the dead. For a start, all your money, friends and family would be long gone, and you'd probably struggle to find work in whatever hyper-advanced society has managed to resurrect you. And there are bigger questions about how the planet would cope with a human population living far longer than it does now.

"We are not going to have to worry about all that right now," says Valentine, frustrated by questions he sees as pointless hypothesising. "The world may have changed in ways we can't even imagine! We could be inhabiting other planets or have modified ourselves to live in other environments."

It's certainly hard to dismiss these ideas completely, given the remarkable progress our

species has made in just the last few decades. And Valentine is confident that a change of mindset is just round the corner.

"If scientists one day freeze a rabbit and bring it back to life, then the idea will spread so fast. People will start to think: 'why am I being buried in the ground? Why am I being cremated? I'll get frozen, and then one day, who knows.' There could be many of these places around the world. This might become the norm."

Valentine himself is not currently signed up to be frozen at the Timeship – he says it would distract from his architectural mission and could look like he was designing "some kind of monument for myself." But his excitement and enthusiasm for this ambitious project is clear. Will the travellers in the Timeship find themselves alive and well in the future, freed from the limitations of today's medical science? Or is it an expensive folly, doomed to result in several thousand bodies denied a proper burial?

There's really only one way to find out – and it involves a very long, very cold wait. 🐇

Tom Ireland is a science writer and editor of *The Biologist*. He tweets from @Tom_]_Ireland



1980s

Cryonics companies start freezing people's heads but not their bodies (known as 'neuros'), based on the idea that our brains could be transplanted, supported by machines or uploaded to computers in the future.

1999

The first baby is born from eggs that have been frozen. Freezing embryos, sperm and other bodily tissue soon becomes a routine part of medicine.

2002/03

The first whole organ, a kidney, is successfully vitrified (turned into a glass-like state), thawed, and re-transplanted back into a rabbit, where it appears to function normally.

2015

Experiments appear to show that microscopic worms can survive cryogenic freezing and retain memories from events that took place before they were frozen.

2016

The Timeship project, headed up by Stephen Valentine (pictured), announces plans to store thousands of patients at a purpose-built facility in Texas. There are thought to be around 250 people currently cryogenically frozen in the world.

A large flock of seabirds, possibly albatrosses, is captured in flight over a body of water. The birds are scattered across the frame, with some in the foreground and others further back. In the background, a range of mountains is visible under a cloudy sky. The overall scene conveys a sense of vastness and natural beauty.

THERE *AREN'T* PLENTY MORE FISH IN THE SEA

Decades of poor fishing practices may spell the end of fish as food. But it's not the end of the line yet, as new innovations could help reverse the damage

WORDS: HELEN SCALES



“FROM THE SURVEY EMERGED A HEADLINE-GRABBING FORECAST: BY 2048, ALL EXISTING FISH STOCKS COULD HAVE COLLAPSED”



reef shark slides past, an arm's length away, then another. And moments later a third. These sleek hunters pay me no attention and seem accustomed to having people nearby. Scuba divers like me flock to visit the sharks and other marine life

flourishing around the remote islands of Palau in the western Pacific Ocean. This special place offers a glimpse of how things used to be before human activities began emptying the oceans.

Palau remains a rare underwater wonderland, in part because the government takes marine protection seriously. In 2015, the country's president, Tommy Remengesau Jr, declared 80 per cent of the nation's waters off limits to fishing. This is one of a new generation of marine reserves. More recently, in August 2016, Barack Obama announced a huge expansion of Hawaii's Papahānaumokuākea marine reserve. It's the biggest yet, a massive 1.5 million square kilometres – around the size of Spain, France and Germany combined.

The drive to set up these reserves, plus various other measures to protect the seas, stems from growing awareness that the oceans are in trouble. It's becoming clear there are no longer plenty more fish in the sea.

In 2006, a prominent group of marine scientists published a paper in the journal *Science* scrutinising the state of the oceans around the world. From their survey of the abundance and diversity of marine life emerged a headline-grabbing forecast: by 2048, all existing fish stocks could have collapsed.

Not all experts agreed on that date, which assumes the present rate of collapse will continue at its current rate – already a third of all fish stocks have collapsed since 1950. Others have re-analysed

the same data and pushed the date forwards to the 2070s or even 2100s. Still, it's a dire prognosis for fisheries that feed billions of people worldwide.

And now, 11 years later, there are very few signs of improvement. “The picture painted in that paper is largely true,” explains Prof Callum Roberts, a marine conservationist from the University of York. “Wild seafood stocks are still declining rapidly.”

Last year a major study, published by marine biologist Dr Daniel Pauly and colleagues from The Sea Around Us project, warned that the world has probably already passed ‘peak fish’. A team of 400 researchers gathered data from small-scale, recreational and illegal fisheries that normally remain under the radar. They showed that the total seafood catch, comprising all the fish, shellfish and other invertebrates caught from the seas worldwide, is far higher than official figures suggest. This may appear to be good news: if more seafood is being caught, maybe the oceans aren't as empty after all. Far more worrying, though, are the trends over time. It had been thought that since the 1990s, the global catch had levelled off and stayed roughly the same year-on-year. These latest, more complete figures indicate that global fisheries peaked at 130 million tonnes in 1996. Since then, catches began to drop by 2 per cent every year. Despite expanding fleets and advancing technologies, fisheries are unable to catch as much as they used to.

WHERE HAVE ALL THE FISH GONE?

Behind the global fishing crisis lies a catalogue of problems. First and foremost, there are simply too many fishing boats chasing fewer and fewer fish. This is partly because of financial subsidies and other perks keeping fisheries afloat. Governments provide cheap fuel for boats, tax rebates, low-interest loans and other measures to maintain fisheries that would otherwise become unprofitable and fold as fish become scarce.

Fishing also physically damages the marine environment. Trawlers and dredgers scrape heavy nets across the seabed, smashing delicate, centuries-old habitats. Huge quantities of unwanted sea life are caught that have no market or quota. This so-called bycatch is usually thrown straight back into the sea, already dead or dying.

Added to all this are convoluted impacts of pollution and climate change. Warming seas are driving certain species towards the poles, rearranging ecosystems and causing coral reefs to bleach and die, while carbon emissions are making oceans more acidic, which weakens shellfish and alters fishes' hearing and behaviour. To make matters worse, fish that end up on our plates are also becoming filled with fragmented plastic. ●

BELOW: Fishing lines and nets lost at sea do not readily break down, so they can continue trapping animals for years



THE STATE OF OUR SEAS

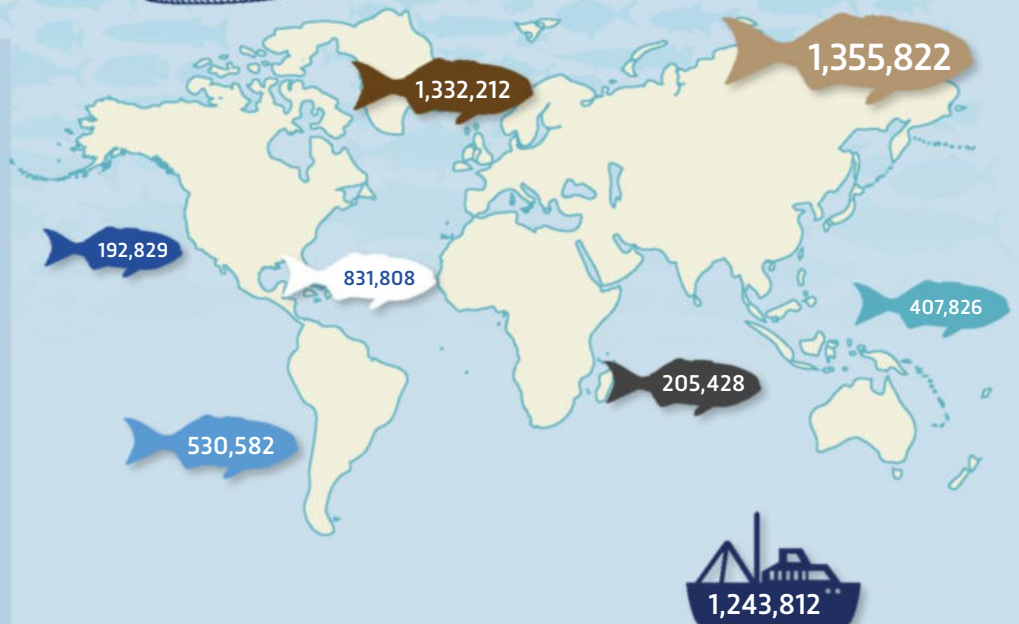
**OVER
2.5**

billion people rely on fish for a major source of protein



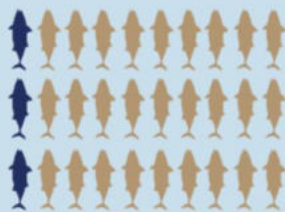
ONE IN FIVE FISH IS CAUGHT ILLEGALLY

Every day, the amount of longlines set out in the oceans would wrap around the globe 500 times



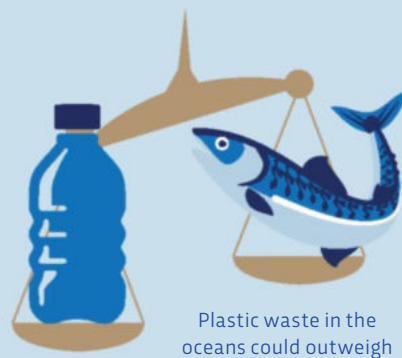
ANNUAL DISCARD RATE (IN TONNES) BY OCEAN REGION

- NORTHEAST PACIFIC
- SOUTHEAST PACIFIC
- NORTHEAST ATLANTIC
- WEST CENTRAL ATLANTIC
- NORTHWEST PACIFIC
- WEST INDIAN OCEAN
- WEST CENTRAL PACIFIC
- REST OF THE WORLD



10%

of the global fish catch is certified as sustainable by the Marine Stewardship Council



Plastic waste in the oceans could outweigh the fish by 2050

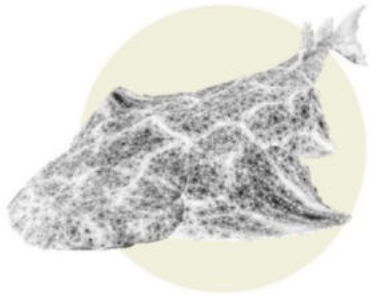
FISH STOCKS

could be declining three times faster than official figures suggest



THE BIGGEST LOSERS

Some species are more sensitive to pollution and fishing than others...

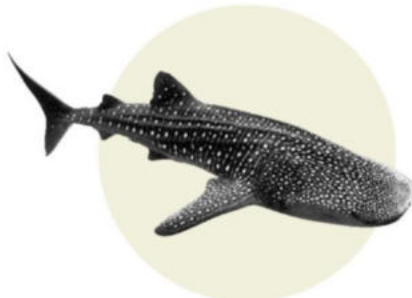


ANGEL SHARK

The angel shark was once common from the North Sea to the Mediterranean. As it lives on the seabed, it is taken as bycatch by trawlers and has been almost completely wiped out. Now it only lives around the Canary Islands.

TOTOABA

Illegal fishing is driving the totoaba to extinction in its native range in the Gulf of California. Its swim bladder, an organ that regulates buoyancy, is worth up to £6,500 a piece in China to make into soup.



WHALE SHARKS

In 2016, the whale shark was listed as endangered by the World Conservation Union because its numbers have halved in the last 75 years. It only becomes sexually mature at between 20 and 30 years old, so populations take a long time to recover.

COMMON SKATE

With a name that's become sadly ironic, the common skate is critically endangered in the Atlantic and Mediterranean, and extinct in the Baltic. Along with some other skate species, its large size makes it vulnerable to being caught in nets.



EUROPEAN EELS

Numbers of young European eels have crashed by up to 95 per cent in the last 30 years. Declines are blamed on habitat loss, pollution and barriers to migration. Eels are born in the Sargasso Sea, before migrating across the Atlantic and up into rivers and streams, where they mature.



Certain fishing methods indiscriminately plunder the seas, sometimes catching vulnerable species, such as sharks, dolphins and turtles

❶ Fixing all these problems is undeniably an immense task; they don't act in isolation but together, often worsening each other. Nevertheless, effective solutions are already available.

SAVING THE SEAS

Marine reserves are a proven way of restoring fish populations. By excluding fishing from particular areas, reserves allow marine species to recover from previous exploitation.

A 2009 study brought together hundreds of papers on the subject and showed that reserves tend to work well in both tropical and temperate waters. Reserves dramatically boost the density of marine species, by 166 per cent on average; species diversity also goes up by around 20 per cent. Reserves also keep habitats healthy and help make ecosystems more resilient to climate change. A well-known example comes from the Philippines. In the 1980s, 10 per cent of the coral reefs around Apo Island were closed to fishing. Twenty years later, the total quantity of the two main targeted fish groups, surgeonfish and jacks, had tripled inside the reserve. Benefits also spill out as adult fish and larvae move into unprotected areas, replenishing the wider seascape. The fishermen of Apo saw a 50 per cent increase in their catches outside the reserve. Similar stories are coming in from reserves around the world.

The portion of the oceans that falls within some form of marine reserve is gradually rising. A major obstacle, though, is enforcement. Many countries lack resources for patrols, especially in very large, remote reserves. "Here you have an activity that becomes invisible when it gets beyond the horizon,"



“CONSUMER CAMPAIGNS HAVE MADE A BIG DIFFERENCE TO THE WAY SUPERMARKETS THINK ABOUT SOURCING THEIR FISH”

says Jackie Savitz, from the non-profit group Oceana. She's heading up a new initiative to make fishing more visible.

Global Fishing Watch (globalfishingwatch.org), which launched in September last year, is a free online tool showing where fishing is happening anywhere in the world. The project uses data from Automated Information Systems (AIS) required on many watercraft over a certain size to avoid them crashing into each other. AIS broadcasts public information via satellite on the vessel's location, heading and speed. These data are being mined to detect which vessels are fishing, where and when.

Oceana brought Google to the party, to help analyse the big data generated by AIS devices and detect the characteristic movements of fishing. The Global Fishing Watch website currently tracks over 35,000 fishing vessels in near real-time; typically data go online around 72 hours from the present. It's hoped governments will use the website to enforce sustainable fisheries regulations, such as closed seasons and marine reserves. Kiribati, a small nation located in the Pacific Ocean, has already used the data to fine a commercial vessel \$1m for illegally fishing inside the Phoenix Islands Protected Area.

Technology is also being applied to deal with bycatch. The conservation group WWF runs Smart Gear, a competition to develop new ways to stop unwanted species being caught. Winners in 2014 included Super Polyshark. These pellets of slow-release non-toxic, biodegradable shark repellent are inserted in the bait that's used on longline hooks. Tests show they reduce the number of sharks that go for the bait and get snagged. Other devices include scarers to reduce seabird deaths, and trapdoors in trawl nets that let turtles and cetaceans escape.

Back in Palau, studies are underway to limit bycatch in the 20 per cent of their national waters where fishing continues. The Nature Conservancy is testing different types of hooks in the tuna longline fishery to reduce the bycatch of sharks and turtles, species highly valued by divers. Every living shark in Palau is worth up to \$2m a year to the dive industry.

RECONNECTING WITH YOUR FISH

Seeing supermarket shelves still stocked with seafood, it can be difficult to make sense of reports of emptying seas. It's true that management successes have allowed some collapsed stocks to recover. In the 1970s, North Sea stocks of herring dramatically collapsed. “After a moratorium on fishing, together with some excellent management approaches, they've rebuilt the stocks,” says Roberts. However, seafood supplies today are largely maintained by fishing in distant waters. Imports account for 90 per cent of seafood eaten in the US and around 60 per cent in Europe. This puts mounting pressure on other regions like West Africa, where there is little supervision to prevent overfishing and habitat loss.

This widening gap between plate and ocean makes it more important than ever for us all to care about where our seafood comes from. “Consumer campaigns have made a big difference to the way supermarkets think about sourcing their fish,” says Roberts. More seafood is being certified as sustainable through eco-labelling schemes and awareness is growing over issues of bycatch and damaging fishing techniques. Plus, shoppers can easily check their seafood while in the supermarket by using apps such as the *Good Fish Guide*. “The more people who come into shops and say that this matters to me, the more likely it is that supermarkets will take note,” Roberts adds. 🐟

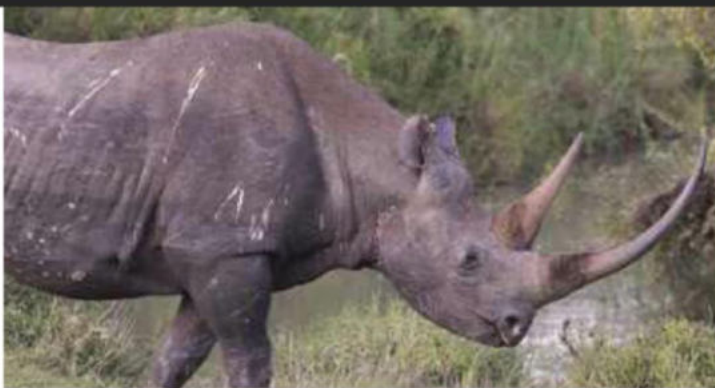
Helen Scales is a marine biologist, writer and keen scuba diver. Her latest book is *Spirals In Time* (£16.99, Bloomsbury).

DISCOVER MORE

🐟 Visit goodfishguide.org to find out more about sustainable fish. You can also download the *Good Fish Guide* as a PDF or as an app for iOS and Android.

Urgent call for help to save the eastern black rhino issued by Fauna & Flora International

Photo: Jelena Aleksić, www.soufire.org.uk



The eastern black rhino has been pushed to the verge of extinction. Just 850 remain. Please return the coupon or visit www.protectrhinos.org to help protect them.

In ten years, eastern black rhino populations could be almost completely destroyed.

Around 850 remain and poaching is at an all time high.

Fauna & Flora International has launched an appeal to raise £96,807 to pay for the conservation of eastern black rhino in the Ol Pejeta Conservancy in Kenya. We need to raise the money urgently – time is running out to save the eastern black rhino.

One of the world's most powerful and awe-inspiring creatures is teetering on the edge of extinction. A hundred years ago, experts say there were around 65,000 black rhino in Africa. Over the decades, the numbers have plummeted due to relentless hunting and poaching, to the extent that there could be as few as 850 eastern black rhino left in the wild.

Unless we act now, the eastern black rhino could be reduced to a few tiny populations in a decade, and we will be the generation responsible for its loss. We cannot let that happen. That's why Fauna & Flora International (FFI) needs your donation today.



Photo: Gill Shaw/FFI

"If you value the natural world, if you believe it should be conserved for its own sake as well as for humanity's, please support FFI."

Sir David Attenborough OM FRS
Fauna & Flora International
vice-president

Rhino horn fetches a huge price in markets like Vietnam. Ruthless international gangs will stop at nothing to get it – they even supply poachers on the ground with equipment and rifles.

But there is a ray of hope. In 2004 Fauna & Flora International helped to purchase Ol Pejeta ranch, a substantial piece of land in Kenya, to create a safe haven for endangered animals. Now

known as the Ol Pejeta Conservancy, it is home to over 100 eastern black rhino.

Specially trained rangers constantly patrol Ol Pejeta to spot and check every single one, every three days. It is gruelling work, as the rangers have to trek miles each day and risk their lives keeping the rhino safe.

By making a donation of £25, you could help recruit and train more rangers, ensuring we can cover more ground and keep the rhino safe. Your gift could help train rangers in military skills and dog handling to help them protect the rhino.

Every day rangers like Stephen Elimlim and his colleagues walk at least 20km. They urgently need trekking boots and camouflaged uniforms, as well as powerful binoculars to spot the rhino so they can protect them from the poachers. Your gift of £35 would help get this vital equipment to the rangers who need it.

So much is possible with your help. Amazingly, we have already seen the numbers of rhino rise in Ol Pejeta, and the population is growing by around 5% each year.

Yet we cannot be complacent. As the poachers grow bolder and become better equipped, the challenge becomes greater day by day. We urgently need to raise £96,807 to train, equip and support the local rangers and help keep the rhino of Ol Pejeta safe. A gift of £100 from you today could assist us in building accommodation for rangers in the heart of the Conservancy, so they can stay one step ahead of the poachers.

Whatever amount you can spare, your gift will help us build on our successes. We know that our approach works, and with your help we can support the use of the same techniques elsewhere across Africa. Your gift really can help us save a species.

Please send a donation by 31 January in order to help ensure the safety and survival of the last few eastern black rhino in the wild. The future of a unique race of animals depends on it. Please complete the donation form now.

Photo: Ol Pejeta Conservancy



Stephen, a ranger at Ol Pejeta Conservancy

How you can help rangers like Stephen to save the eastern black rhino

- £25 could help buy a pair of binoculars, essential for surveying the rhino population
- £35 could help pay for a uniform and boots for a newly trained ranger, giving them protection and camouflage
- £100 could go towards training ranger and dog teams
- One exceptional gift could make a huge difference - £1,000 could fully equip and train a ranger

Cut the coupon below and return it with your gift to FFI. Alternatively, go to www.protectrhinos.org or call 01223 749019.

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HELEN CZERSKI... WHY DO RICE KRISPIES GO SNAP, CRACKLE AND POP?

“FOR ME, THE MOST ASTONISHING THING ABOUT THIS MECHANISM IS THAT SO MUCH SOUND GETS OUT”

It's one of those sounds that's so familiar, we've almost forgotten to hear it. You pour milk on to your Rice Krispies and immediately there's a jolly, crackling noise that sounds like a log fire with the volume turned down, or perhaps

like mice running around on tiny bubble wrap. It would be completely weird if we weren't so used to it – how can starch so fragile that it's barely there make such a loud noise? I was set the task of finding out.

Each little Rice Krispie has the structure of a sponge. If you cut one in half, you can see that it's full of tiny air pockets surrounded by very thin walls. Sometimes the starch walls are so thin that they're transparent, and quite often the outside of a Rice Krispie has got holes in it where an expanding bubble of gas on the inside burst through. The walls are made of a mixture of long carbohydrate molecules (that's the starch) and sugar, and together they form a material a bit like a glass. It's brittle, so if you crush it, you hear sharp snaps as the thin layers shatter. That makes sense when it's dry, but surely wet starch is soggy, and is much more likely to squish than shatter!

There's quite a lot of variety in the popping sound that you get. If you try putting water rather than milk on your Rice Krispies, the crackling is loud and immediate. And you can see bubbles of air being expelled from the insides of the cereal. Skimmed milk produces quieter crackling than water, and full fat milk is quieter still. I also tried different temperatures, and found that hot milk is much noisier than cold milk. So I suspect that the speed and loudness of popping is dependent on the viscosity of the milk – when it's straight from the fridge it's twice as viscous as it is at body temperature. And whole milk is about twice as viscous as water. Viscosity is important for how fluids flow – a more viscous liquid tends to flow more slowly because the fluid is resisting the flow. So that gets us to what's happening inside the Rice Krispies. The appearance of bubbles tells us that the milk is seeping slowly into the air spaces. The sound isn't coming from the bubbles, so it must be coming from the inside. What's going on in there?

The least viscous liquid of all, hot water, will rush in to fill the air pockets pretty quickly. Water is attracted



to starch, and so it will crawl inside through the gaps, creeping along the walls and dragging other water behind it. The problem is that those pockets are already full of air. So the best explanation seems to be that as the air gets squeezed by milk advancing on one side of the pocket, the pressure in each pocket goes up until eventually it bursts the fragile starch wall on the other side. That's what makes the snap that we hear. The milk keeps creeping in, pushing up the pressure pocket by pocket and cracking each one as it goes. The faster the milk advances, the louder and more frequent the crackling, which is why less viscous milk gives you noisier popping sounds.

For me, the most astonishing thing about this mechanism is that so much sound gets out. Sound

doesn't travel well through mixtures of air and water, which suggests that the original crack must be extremely loud. But it's nice to think that even a breakfast cereal contains a few hidden mysteries – the subtlety and sophistication of the everyday world is not to be underestimated!

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, is out now (£8.99, Transworld).

NEXT ISSUE: WHY DON'T PLANES ALWAYS LEAVE TRAILS?



HAPPIEST

MEET THE

PEOPLE ON THE PLANET

It's January. It's cold. Christmas is over and summer feels a long way off. So how, and why, do the world's happiest people keep smiling through the long winter months?

WORDS: JHENI OSMAN



nce again, it's been raining all day. It got dark hours ago. And a bitterly cold January night beckons in the city of Copenhagen. Many people would find all this pretty

depressing. But not most Danes.

In 2016, Denmark was ranked as the happiest nation on the planet in the World Happiness Report. This might sound surprising given that in mid-winter the country is plunged into darkness for 16 hours a day, deprived of that supposed vital ingredient of happiness: sunshine. So what are their secrets?

The annual World Happiness Report typically assesses criteria such as: per capita income; life expectancy; people's freedom to make life decisions; generosity; social support; and corruption in government

and business. For the 2017 report, researchers are looking in depth at Africa and China, happiness in the workplace, happiness over the course of life in general, and the sources and consequences of trust – the vital glue for ensuring stable social foundations.

"The most surprising thing we've found is that building the positives is more important than identifying and curing the negatives," says John Helliwell, professor emeritus of economics at the University of British Columbia. He co-edits the World Happiness Report and is remaining tight-lipped about who he thinks will take the number one spot this year – results are due in March. "The aim of the report is to increase public and policy awareness of the importance and meaning of internationally comparable measures of the quality of life," he adds.

Helliwell and his colleagues believe that happiness provides a better indicator of ●

● human welfare than separate measures of income, poverty, education, health and good government. And they have found that people are happier living in societies where there is less happiness inequality. However, results show that happiness inequality has increased significantly in most countries, in almost all global regions, and for the population of the world as a whole.

DOES MONEY BUY HAPPINESS?

It's not surprising to learn that wealth does play a small part in happiness. After all, incomes are more than 25 times higher in the happiest countries than in the least happy ones. "Income is one of the bigger elements in explaining international differences," says Helliwell. "Having at least sufficient material resources is one of the prime supports for a good life. But, of course, they are not the major part of the story."

Meik Wiking, CEO of the Happiness Research Institute, a Copenhagen-based think tank, agrees that money is not the sole root of happiness: "The Danes decouple wealth and well-being. We focus on the small things that really matter, including spending more quality time with friends and family, and enjoying the good things in life."

Wiking is the author of *The Little Book Of Hygge: The Danish Way To Live Well*. Hygge (pronounced 'hooga') is the latest buzzword on the lips of every advertising agent, lifestyle magazine editor and blogger. It is usually translated as 'cosiness', but Danes would say it's much more than that.

"Hygge has been called everything from the 'art of creating intimacy' to 'cocoa by candlelight'," says Wiking. "Some of the key ingredients are togetherness, relaxation, indulgence, presence and comfort. The true essence of hygge is the pursuit of everyday happiness and it's basically like a hug, just without the physical touch."

Now, before you start thinking that all you need to be truly happy is to win the lottery so that you can settle down in a blissful state of hygge and never lift another finger, think again. Even if you're wealthy, work is a great tonic for gloominess.

"It is not work itself, but how it is done, with whom, and in what circumstances, that creates or destroys happiness," says Helliwell. "People are happier doing things with other people, especially if they feel they're doing important things in a friendly and trustworthy environment. This is true for life both in and out of the workplace. People who work in a high-trust workplace and think of their superior more as a partner than a boss are as happy on weekdays as on weekends."

And there we were feeling miserable about the decades of hard toil that stretch ahead of us...

SUBJECTIVE SMILES

So, the next big question: can one really rate happiness subjectively? Surely, surveys are subject to individual bias? We all know how we Brits like

to put a brave face on, picnic on a rainswept beach (just because the Met Office told us it was going to be a scorcher), and always say 'Fine, thanks!' when someone asks us how we are (even if we're going through a crushing bout of existential angst, having spilt our cup of tea).

"There are three different types of subjective well-being measures," explains Helliwell. "These include positive affect [how we experience positive emotions], negative affect [how we experience negative emotions], and life evaluations, where respondents say how happy they are with their lives as a whole." According to Helliwell, life evaluations tend to be determined by individual circumstances and are more variable among countries. All three measures are subjective reports based on the individual's responses – just like when doctors ask patients to report on their pain levels.

Yet not all scientists are satisfied with these subjective assumptions. Associate professor Wataru Sato and his team at Japan's Kyoto University have used scans of the brain to try to determine which area is involved in feeling happy. Their results showed that volunteers who rated highly on happiness surveys had more grey matter mass in the precuneus, which is involved in self-reflection and consciousness.

But scientists aren't just looking at the brain. They are also turning to genetics to determine why some of us are happier than others.

IN THE GENES

Researchers at Vrije Universiteit in Amsterdam have isolated the parts of the human genome that may explain the differences in how we each experience happiness. After analysing the DNA of over 298,000 people from around the world, the team found three genetic variants for happiness. Crucially, they discovered that two of the variants are linked with differences in the symptoms of depression, a mental disorder that is one of the greatest medical challenges of our time. ●

BELOW: Denmark's capital city of Copenhagen, where residents commute by bicycle and there's always time for a cinnamon bun. What's not to love?



PHOTO: GETTY ILLUSTRATION: DANBRIGHT/LOST STUDIO



HYGGE YOUR HOME

Meik Wiking, CEO of the Happiness Research Institute, offers his five top tips for creating a cosy sanctuary

1 MAKE A HYGGEKROG

Every home needs a hyggekring, which roughly translates as 'a nook'. It is the place where you love to snuggle up with a book and a hot drink.

2 BRING IN NATURE

Danes feel the need to bring the entire forest inside. Any piece of nature you find is likely to get the green light. Leaves, flowers, pine cones... basically, think how a Viking squirrel would furnish a room.

3 THINK TACTILE

A hyggelig interior is not just about how things look, it is just as much about how things feel.

Letting your fingers run across a warm, wooden table is a different feeling from being in contact with something made from cold steel or plastic.

4 LIGHT CANDLES

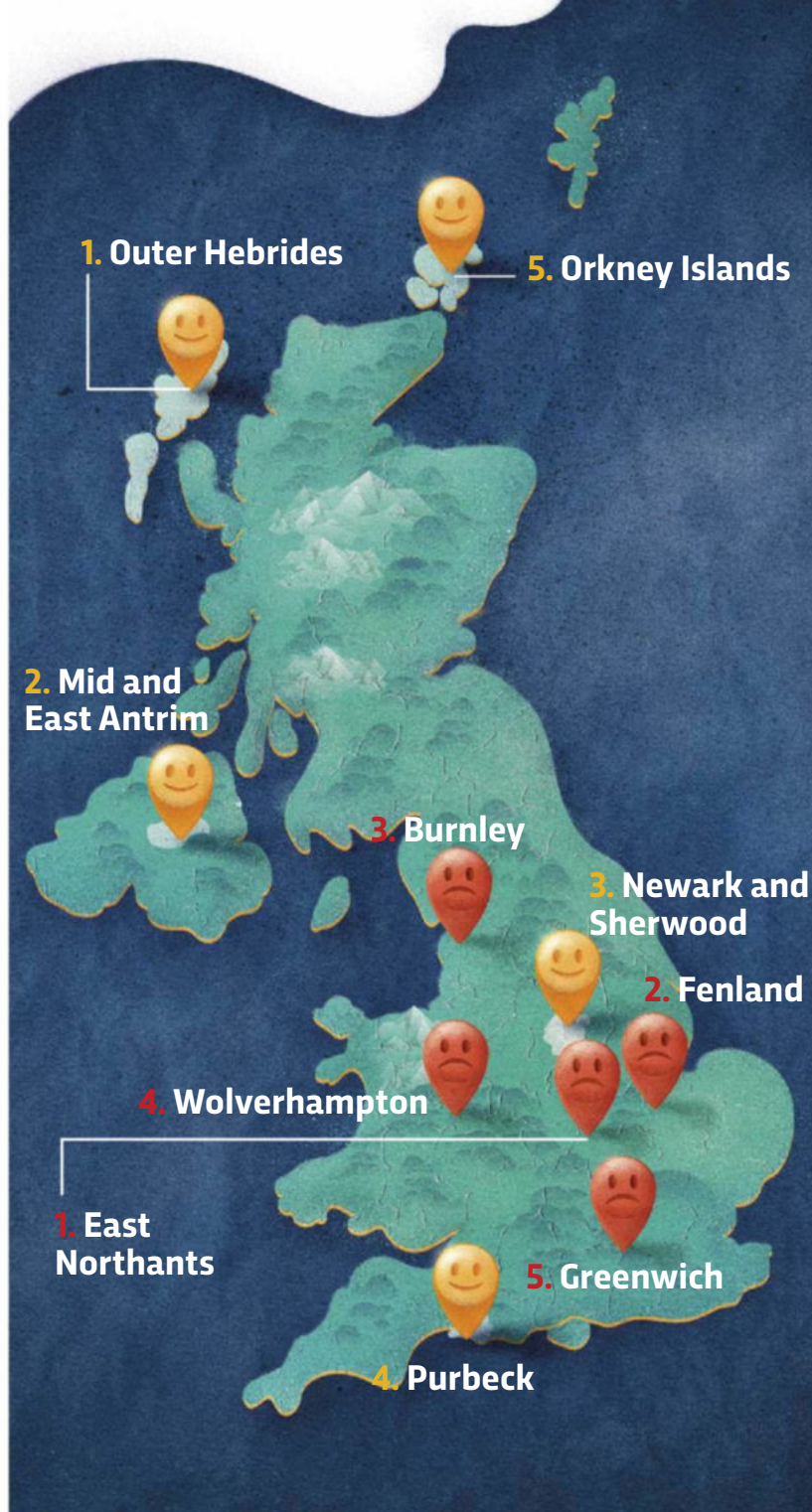
As soon as it gets dark, Danes tend to light candles, especially in the winter. Candles instantly create a cosy mood and offer a softer light than overhead bulbs.

5 LINGER LONGER

Danes love to linger, particularly after a delicious meal. While many people around the world start to clear up as soon as a dinner party is finished, Danes just relax – giving time for mindfulness.

“The Danes focus on the small things that really matter, including spending quality time with friends and family”

THE HAPPIEST PLACES IN THE UK



The Office for National Statistics wanted to find out the happiness levels of people in the UK. Participants answered four questions, using a scale from zero to 10. Here, we've listed the UK's five happiest and five unhappiest places, which were ranked according to the results. Can't see

your area? Visit bit.ly/happy_area for a more in-depth map of the UK.

Do you live in the happiest (or unhappiest) area? Let us know your thoughts by sending an email to reply@sciencefocus.com or drop us a message on Twitter @sciencefocus



“The genetic variants that influence subjective well-being largely overlap with those that explain differences in depressive symptoms,” says Prof Meike Bartels, who carried out the research. According to Bartels, this overlap indicates that it could be useful to promote well-being in conjunction with preventing and treating mental illness. So it seems that taking steps to keep your population happy is just as important as safeguarding them from mental illness.

Meanwhile, a paper published in the *Journal of Happiness Studies* suggests that the DNA of people who regard themselves as happy is more likely to contain a specific gene variant involved in sensory pleasure and pain reduction.

Elsewhere, research at the University of Warwick has shown that national levels of happiness depend on how close we are genetically to our smiley friends, the Danes.

“Our research showed that the ‘genetic distance’ of a country from Denmark correlates with the average life satisfaction in that country,” says Proto.

Intriguingly, the research also showed a link between mental state and the version of the gene that influences the uptake of serotonin. The serotonin transporter gene comes in two forms: long or short. According to the research, the short variation, which some scientists consider to be linked to depression, is more common in countries that report lower average levels of life satisfaction.



LEFT: Spending quality time with friends and family is vital for happiness, according to the Danes

BELOW: Economist John Helliwell thinks that happiness is a better measure of well-being than wealth or education



“The ‘genetic distance’ of a country from Denmark correlates with the average life satisfaction in that country”

While the link is controversial, the short variation has also been associated with higher scores on neuroticism and lower life satisfaction. Denmark and the Netherlands appear to have the lowest percentage of people with this short variation.

HAPPINESS IS LAW

The great news is that we British are not too far removed genetically from our Nordic cousins across the sea. “The British have no excuse – they are sufficiently close to the Danish in terms of genetic distance,” says Proto, adding jokingly: “Although weather is also an important determinant of subjective well-being!”

Back in 2010, David Cameron commissioned a study into the happiness of the British and, according to the government, happiness rates are on the rise in the UK. Politicians have latched on to the importance of happy citizens. Ministers of happiness have been appointed in Ecuador, the

United Arab Emirates, Venezuela and Bhutan. In the latter, happiness is now embedded in the national constitution. And the National Academy of Sciences in the US has formed a panel to establish how happiness measurements can help develop policy.

So, is the world becoming a happier place?

“There’s not much of a global trend yet,” says Helliwell. “Data is only starting to become available for a long enough period to find significant trends among nations. Over the very long term, even if lives in less happy countries are becoming better, we might expect to see that for the world as a whole there may be some adjustment in expectations as people raise their sights and see even better potential lives.”

Maybe it would do us all good to bear in mind the wise words of one of the Founding Fathers of the US, Benjamin Franklin, who said: “Happiness consists more in small conveniences of pleasures that occur every day than in great pieces of good fortune that happen but seldom”. 🍀

Jheni Osman is author of *100 Ideas That Changed The World*, and presenter of *SciTech Voyager*.

DISCOVER MORE



Find out where in Britain you’d be happiest, by taking this interactive test from BBC iWonder at bbc.in/1br6VME

WATCH
**TRUST ME, I'M
A DOCTOR**

BBC TWO,
THIS JANUARY



SMALL WORLD

We often think of bacteria and other microbes as 'bad'. But human bodies – and particularly our digestive systems, pictured here – teem with numerous species of tiny organisms that play an essential role in keeping us healthy and happy.



UNDERSTAND THE HUMAN MICROBIOME

We are not alone. Bacteria and other microscopic organisms in their thousands share our bodies, influencing our lives in more ways than we'd ever expected

WORDS: MUN-KEAT LOOI

In any human body there are around 30 trillion human cells, but an estimated 39 trillion microbial cells including bacteria, viruses and fungi that live on and in us. Due to their small size, these organisms make up only about 1-3 per cent of our body mass, but this belies their tremendous power and potential.

We have around 20-25,000 genes in each of our cells, but our microbiome potentially holds 500 times more. Moreover, the ability of microbes to evolve quickly, swap genes, multiply and adapt to changing circumstances give them – and us, their hosts – remarkable abilities that we're only now beginning to fathom.

Where do they live?

The human body provides a broad range of environments, and microbes are capable of living in all of them. Each part of the body is a different type of ecosystem, like a planet with different continents and climates, the inhabitants of which have adapted to the characteristics of each location.

Our faces and hands are dry and cool. They're exposed to the elements, not to mention a constant stream of immigrant microbes every time we touch or come close to another thing. Nooks and crannies like the armpits have a lot to offer bacteria, being moist, warm and dark. The average human foot is even better, with 600 sweat glands per square centimetre –

hundreds more than the armpits – that secrete a soup of salts, glucose, vitamins and amino acids, providing the perfect diet for a colony of bacteria.

Then there is the gut, where thousands of native bacteria live in partnership with us. They survive a hostile environment of darkness, high acidity and low oxygen, in what is a tumultuous river flushing through the stomach and intestines.

Where do these microbes come from?

Three-quarters of your microbiome can be traced back to your mother. The womb is a sterile place, free of microbes (at least we think so at the

moment). But when we exit via the birth canal, we're bathed in vaginal microbes. This literal baptism of bacteria may be vital to a healthy start in life – babies who are born through caesarean section are more likely to develop allergies, asthma, coeliac disease and obesity later in life.

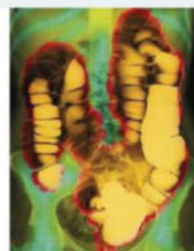
We also ingest around a million microbes in every gram of food, and our diet has a direct impact on which species thrive in our gut microbiome. If we change diets, from meat-eater to vegetarian, for example, the gut bacteria changes accordingly.

Similarly, as we go through life, moving from one environment to ●



We pick up the majority of our microbiome from our mothers when we are born

The human large intestine, seen here in yellow, is filled with many microbe species



➤ another, we're exposed to microbes from different people and places. Every home has a distinctive microbiome that comes from the people who live in it. Just 24 hours after moving into a new home we've colonised it with our microbes. And those who grow up in a household with pets are exposed to a far bigger array of microbes, which is no bad thing. Scientists suspect that a lot of common modern allergies, such as hay fever, are triggered by an immune system that didn't learn to live with such microorganisms at an early age.

What do our microbes do?

Lots. In the gut, they control the storage of fat and assist in activating genes in human cells involved with absorbing nutrients, breaking down toxins and creating blood vessels. They help to replenish the linings of the gut and skin, replacing damaged and dying cells with new ones.

Equally vital is their role in preventing illness. Our native microbes compete with invading ones, preventing them from getting a foothold. We're born with an immune defence system only partially formed. It's the interaction with microbes that shapes it, influencing the classes of immune cells that are generated and the development of the organs that make and store them. As Ed Yong says in his book *I Contain Multitudes*, "The

immune system is not innately hardwired to tell the difference between a harmless symbiont and a threatening pathogen... it's the microbe that makes that distinction clear."

Our microbiome even affects how we smell. Different microbe species might convert sweat into the smell of onions, or testosterone into the stink of urine, which act as strong signals for our friends and foes. These smells are highly personal: studies have found people can be identified just from their sweaty T-shirts.

Scientists also think that our microbiome may be a significant contributor to jetlag. The change in sleep patterns puts the rhythm of our gut bacteria out of sync with our own behaviour, so different species are active at the wrong times. In fact, sleep is just one of the many ways through which microbes might affect our mood and behaviour.

Finally, our microbiome helps dispose of us in what has been dubbed the 'thanatomicrobiome'. After we die, the immune system stops working, leaving our microbes to spread freely. Our gut bacteria start digesting the intestines, and the surrounding tissues, from the inside out. Eventually they invade the capillaries and lymph nodes, spreading to the liver, spleen, heart and brain as they feed on the chemical cocktail that leaks out of damaged cells. ➤



LEFT: Our individual microbiome is so unique that we can be identified by the smell of a sweaty T-shirt

JARGON BUSTER

ANTIBIOTIC

This is a medicine that inhibits the growth of, or destroys, microorganisms. The antibiotics are actually produced by bacteria themselves as a form of survival (or, some scientists think, 'communication' between each other).

DYSBIOSIS

This is a disruption to the harmony of symbiosis, where the microbial community shifts in a way that harms its host. The phrase is often applied to the human gut microbiome, where it describes a condition caused by too few beneficial bacteria and an overgrowth of bad bacteria, yeast, and/or parasites.

MICROBE

Single-celled organisms so tiny that millions can fit into the eye of a needle.

MICROBIOTA

'Microbiota' refers to a set of microscopic organisms. 'Microbiome' originally referred to their genomes – all the DNA of these organisms – but is now sometimes used in place of 'microbiota'.

PROBIOTIC

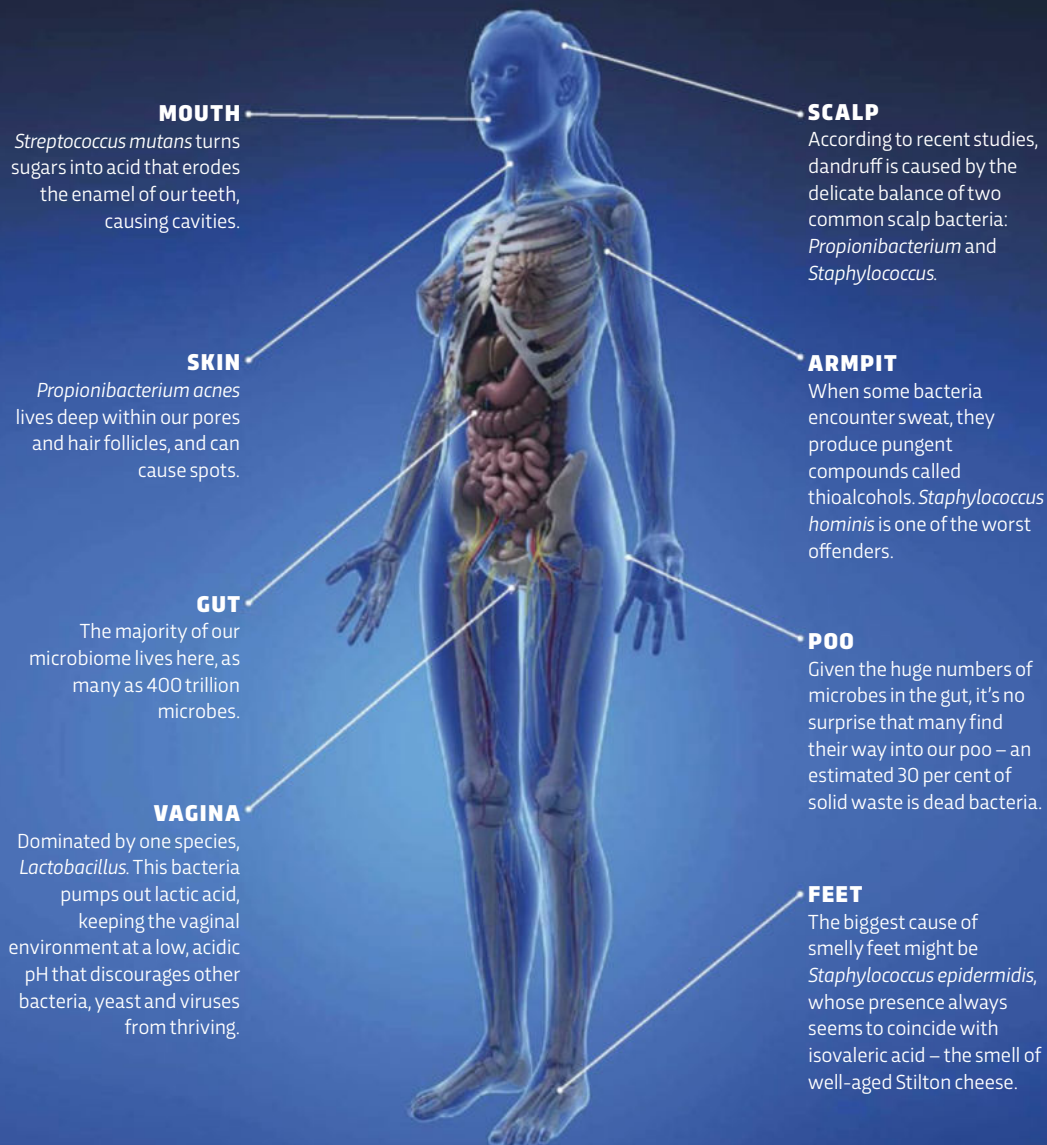
A substance that stimulates the growth of microorganisms.

SYMBIOSIS

This refers to the interaction between two different organisms living in close physical association, typically to the advantage of both.

A WHISTLESTOP TOUR OF HUMAN MICROBES

Say hello to the organisms that call our bodies home



WHAT WE STILL DON'T KNOW

1 CAUSE OR CONSEQUENCE

It's hard to tell if the microbiome is responsible for changes in diseases and behaviour, or if diseases and behaviour are responsible for the microbiome. Experts are piecing together how gut microbes influence the brain through the hormones and molecules they produce, but no one knows how important these are. Drug companies, keen for new ways to treat neurological disorders, are investing money into research.

2 HOW DIFFERENT SPECIES RELATE

The networks and interplays between different species of microbes is incredibly complicated. Then there's how external factors come into play. We know, for example, that the balance of two groups of bacteria – the Firmicutes and Bacteroidetes – affect obesity, but the link still isn't clear or consistent enough to know how we might influence it. And even if we were to find a potential treatment, there's no telling if the body would accept it.

3 WHAT MAKES A HEALTHY MICROBIOME

How do you know if a microbiome is in disarray? Is a gut without a particular species unhealthy? And in comparison to what? Defining what is 'normal' or 'healthy' for a human microbiome is important, and this may differ widely between countries, regions, communities, cities, and whether someone is young or old, rich or poor, outgoing or solitary. This is a further challenge to the dream of personalised medicines for everyone.



In one tweet...

I am more than an individual. I am the sum of many parts, a walking ecosystem. And that balance must be carefully maintained.

● It's no surprise our gut microbiome is implicated in so much. Trillions of microbes live here, the majority of which are in the large intestine. Here, they help digest our food, releasing nutrients we otherwise wouldn't have access to. They produce vitamins and minerals, breaking down toxins and harmful chemicals. Our native *E. coli*, for example, makes vitamin K.

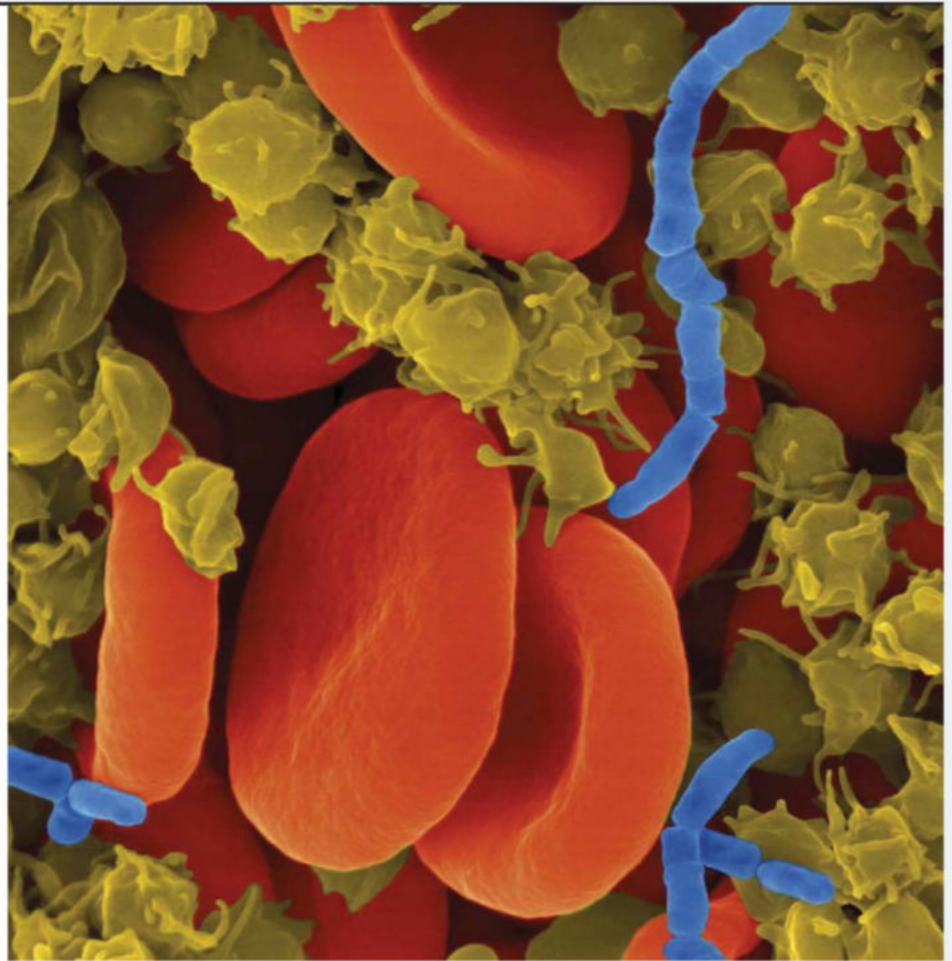
In total, there are between 500 and 1,000 microbial species living in the gut, including *Bifidobacterium bifidum*, which makes lactic acid and acetic acid to help digest our food, and *Methanobrevibacter smithii* – not a bacteria but a separate kind of microbe called an archaea – that converts carbon dioxide and hydrogen gases into methane (the smelly component of farts). Our gut bacteria may affect our weight by changing how much energy we extract from food. Different microbes favour different diets – some are good at breaking down plants, others fats.

In addition to releasing nutrients and regulating our immune system, our gut microbiome also balances hormone levels. The activity of microbes can stimulate cells in the gut to release large quantities of the neurotransmitter serotonin, which may affect signalling in the brain.

What if things go wrong?

Generally, bad things happen when the balance of our gut microbiome is disrupted. At the simplest level, sickness can develop when normally harmless bacteria stray from their usual habitat. *Enterococcus faecalis* is part of the normal gut ecosystem. But if it gets into open cuts or your urinary tract, it can cause infections. Sepsis occurs when our gut microbes accidentally cross into our blood.

Our native gut bacteria can interfere with medicines. Paracetamol is more effective for some people, thanks to their gut bacteria. And on the extreme end of the scale, the colon cancer drug Irinotecan can be turned toxic by some strains of gut bacteria. Meanwhile, Sulfasalazine, a drug for rheumatoid



If our gut microbes (blue) stray into the bloodstream, they can cause infections like sepsis

arthritis, only works if gut microbes convert it into an active state.

Obese people have different gut microbes to slimmer people, with research in mice indicating that transplanting bacteria can affect how much a mouse will eat (studies on people have been less conclusive).

Research over the past few decades has shown how stress – starvation, lack of sleep, separation from a parent, overcrowding, noise – can change the gut microbiome, at least in mice. Psychiatric and digestive problems often go together. Drinking lots of alcohol makes the gut leakier, allowing microbes to more readily influence the brain. And our gut microbiome gets less stable in old age.

All of these problems may be traceable back to a disruption of the natural microbial balance, what

scientists call 'dysbiosis'. And once disrupted, it's not so easy to get back.

Do probiotics actually benefit us?

The idea is sound: by adding particular species of gut bacteria we can alter the balance of our microbial communities to provide health benefits. Yet commercially sold probiotics probably don't make much difference. Most contain perhaps a few hundred billion bacteria, 100 times fewer than naturally found in the gut. Plus, they are often not important members of the gut microbiome, and don't have what it takes to colonise and stay there for long enough to make a difference.

The BBC programme *Trust Me, I'm A Doctor* is carrying out a study to see whether off-the-shelf probiotic yoghurts contain sufficient live

1 A FORCE FOR GOOD

Microbes are the Earth's longest living creatures, and every living thing on the planet lives in partnership with them. Though we often think of bacteria, viruses and fungi as being the cause of disease, they are actually more benevolent than malevolent. Indeed, without them we wouldn't be the humans – or individuals – we are today.

2 OUR INVISIBLE ARMY

Microbes are the hidden workers behind the circle of life, affecting our mood and our behaviours, and even cleaning up our bodies after we die. They are both servant and master to us, or puppet and puppeteer, depending on your point of view.

3 A UNIQUE COCKTAIL

Our mothers kick-start our microbiome through vaginal birth and adjust that via antibodies in breast milk. The rest is shaped by our genetics, our companions, where we live, the food we eat and the drugs we take.

BELOW:
Bacterial infections of *C. difficile* (pictured) can be beaten by a faecal transplant

cultures to change the microbiota of 30 healthy volunteers. Do the microbes even reach the gut? And if so, how long do they survive and are there any health benefits?

Where probiotics *can* be beneficial is after antibiotic treatments. Antibiotic medicines are weapons of mass destruction as far as the microbiome is concerned. One study conducted at the University of Valencia found that it took four weeks for the gut bacteria to re-establish themselves following a course of antibiotics, and certain bacteria did not reappear at all. The right probiotics, chosen by a doctor, can help repopulate that ecosystem.

What are faecal transplants?

It's exactly what it sounds like – taking a sample from someone else's poo and transplanting it into your body. And as gross as that sounds, it's actually very viable. Around 30 per cent of your poo is made up of gut bacteria, and transplanting the good bacteria from a healthy patient to a sick one could combat malicious infections, particularly those caused by bacteria such as *Clostridium difficile* and MRSA, which are resistant to most antibiotics. Faecal transplants have been used to treat hundreds of patients, more than 90 per cent of whom recovered from their illness. In a 2012 trial, faecal transplants cured 15 out of 16 *C. difficile*-infected

Trust Me, I'm A Doctor will be investigating the effectiveness of probiotic drinks



patients, versus 7 out of 26 with an antibiotic. As the results were so successful, the trial was halted and the antibiotic group was then treated with faecal transplants.

How do we study the microbiome?

Much research into microorganisms goes on in dishes and test tubes in the lab, or in organisms such as mice – particularly specially bred 'germ-free' mice that are born into a sterile environment and are never exposed to other microbes until scientists introduce them to specific strains.

There are also large-scale studies using the latest DNA sequencing technology. The US launched the Human Microbiome Project in 2008, a \$115m attempt to map the genes of all the microbes found in the human body – which species are where, which are 'core' to the body and which are transient. So far, the project has characterised more than 1,300 strains taken from 300 people.

It's been joined by other big projects, including MyNewGut, a €9m EU project that's looking for microbiome-based dietary recommendations, which could help to reduce the risk of developing brain-related disorders.

If our microbiome suddenly disappeared, could we survive?

We might get by for a few weeks, possibly even years, but in the long run our health would suffer. We couldn't eat all the foods we've become used to, because we couldn't break them down or we wouldn't get enough energy and nutrients out of them. And we'd soon find ourselves under attack from external microbes that suddenly don't have to compete with a native microbial army.

Without our microbiome, it's arguable how 'successful' we would be as a species, or whether humans would be what we are today. 📌

Mun-Keat Looi is a science writer and editor.

NEXT MONTH: HOW DO WE KNOW WHAT'S AT THE CENTRE OF THE EARTH?





PHOTO: GETTY

Should we stop setting homework?

THE FRENCH PRESIDENT THINKS THAT
HOMEWORK SHOULD BE BANNED. IS HE
RIGHT? SHOULD STUDENTS BE FREED
FROM THIS DAILY CHORE?

WORDS: DR GERALD LETENDRE

Gerald is a professor of education at Pennsylvania State University.



e've all done it: pretended to leave an essay at home, or stayed up until 2am to finish a piece of coursework we've been ignoring for weeks. Homework, for some people, is seen as a chore that's 'wrecking kids' or 'killing parents', while others think it is an essential part of a well-rounded education. The problem is far from new: public debates about homework have been raging since at least the early-1900s. Ironically, the conversation surrounding homework often ignores the scientific 'homework' that researchers have carried out. Many detailed studies have been conducted, and can guide parents, teachers and administrators to make sensible decisions about how much work should be completed by students outside of the classroom.

So why does homework stir up such strong emotions? One reason is that, by its very nature, it is an intrusion of schoolwork into family life. I carried out a study in 2005, and found that the amount of time that children and adolescents spend in school, from nursery right up to the end of compulsory

education, has greatly increased over the last century. This means that more of a child's time is taken up with education, so family time is reduced. This increases pressure on the boundary between the family and the school.

Plus, the amount of homework that students receive appears to be increasing, especially in the early years when parents are keen for their children to play with friends and spend time with the family.

Finally, success in school has become increasingly important to success in life. Parents can use homework to promote, or exercise control over, their child's academic

trajectory, and hopefully ensure their future educational success. But this often leaves parents conflicted – they want their children to be successful in school, but they don't want them to be stressed or upset because of an unmanageable workload.

However, the issue isn't simply down to the opinions of parents, children and their teachers – governments also like to get involved. In the autumn of 2012, French president François Hollande hit world headlines after making a comment about banning homework, ostensibly because it promoted inequality. The Chinese government has also toyed with a ban, because of concerns about excessive academic pressure being put on children.

The problem is, some politicians and national administrators regard regulatory policy in education as a solution for a wide array of social, economic and political issues, perhaps without considering the consequences for students and parents.

DOES HOMEWORK WORK?

Homework seems to generally have a positive effect for high school students, according to an extensive range of empirical literature. For example, Duke University's Prof Harris Cooper carried out a meta-analysis using data from US schools, covering a period from 1987 to 2003. He found that homework offered a general beneficial impact on test scores and improvements in attitude, with a greater effect seen in older students. But dig deeper into the issue and a complex set of factors quickly emerges, related to how much homework students do, and exactly how they feel about it.

In 2009, Prof Ulrich Trautwein and his team at the University of Tübingen found that in order to establish whether homework is having any effect, researchers must take into account the differences both between and within classes. For example, a teacher may assign a good deal of homework to a lower-level class, producing an association between more homework and lower levels of achievement. Yet, within the same class, individual students may vary significantly in how much homework improves their baseline performance. Plus, there is the fact ●

“Over the last century, the amount of time that children and adolescents spend in school has greatly increased”



1 For decades, dogs have been taking the rap for unfinished homework

2 Too much homework and a lack of support may demotivate students

3 Less homework can reduce stress levels of children, which may improve their health





It can be hard for teachers to know how much homework to set, because student abilities vary between and within classes



François Hollande says homework is unfair, as it penalises children who have a difficult home environment

● that some students are simply more efficient at completing their homework than others, and it becomes quite difficult to pinpoint just what type of homework, and how much of it, will affect overall academic performance.

Gender is also a major factor. For example, a study of US high school students carried out by Prof Gary

Natriello in the 1980s revealed that girls devote more time to homework than boys, while a follow-up study found that US girls tend to spend more time on mathematics homework than boys. Another study, this time of African-American students in the US, found that eighth grade (ages 13-14) girls were more likely to successfully manage both their tasks and emotions around schoolwork, and were more likely to finish homework. So why do girls seem to respond more positively to homework? One possible answer proposed by Eunsook Hong of the University of Nevada in 2011 is that teachers tend to rate girls' habits and attitudes

towards work more favourably than boys'. This perception could potentially set up a positive feedback loop between teacher expectations and the children's capacity for academic work based on gender, resulting in girls outperforming boys. All of this makes it particularly difficult to determine the extent to which homework is helping, though it is clear that simply increasing the time spent on assignments does not directly correspond to a universal increase in learning.

CAN HOMEWORK CAUSE DAMAGE?

The lack of empirical data supporting homework in the early years of education, along with an emerging trend to assign more work to this age range, appears to be fuelling parental concerns about potential negative effects. But, aside from anecdotes of increased tension in the household, is there any evidence of this? Can doing too much homework actually damage children?

Evidence suggests extreme amounts of homework can indeed have serious effects on students' health and well-being. A Chinese study carried out in 2010 found a link between excessive homework and sleep disruption: children who had less homework had better routines and more stable sleep schedules. A Canadian study carried out in 2015 by Isabelle Michaud found that high levels of homework were associated with a greater risk of obesity among boys, if they were already feeling stressed about school in

“Banning homework would mean that gifted or motivated pupils would not be able to benefit from increased study”



Parents who play an active role in homework routines can help give their kids a more positive experience of learning

general. It is also worth noting that too much homework can create negative effects that may undermine any positives. These negative consequences may not only affect the child, but also could also pile on the stress for the whole family, according to a recent study by Robert Pressman of the New England Centre for Pediatric Psychology. Parents were particularly affected when their perception of their own capacity to assist their children decreased.

What then, is the tipping point, and when does homework simply become too much for parents and children? Guidelines typically suggest that children in the first grade (six years old) should have no more than 10 minutes per night, and that this amount should increase by 10 minutes per school year. However, cultural norms may greatly affect what constitutes too much. A study of children aged between 8 and 10 in Quebec defined high levels of homework as more than 30 minutes a night, but a study in China of children aged 5 to 11 deemed that two or more hours per night was excessive. It is therefore difficult to create a clear standard for what constitutes as too much homework, because cultural differences, school-related stress, and negative emotions within the family all appear to interact with how homework affects children.

SHOULD HOMEWORK BE BANNED?

In my opinion, even though there are potential risks of negative effects, homework should not be banned.

Small amounts, assigned with specific learning goals in mind and with proper parental support, can help to improve students' performance. While some studies have generally found little evidence that homework has a positive effect on young children overall, a 2008 study by Norwegian researcher Marte Rønning found that even some very young children do receive some benefit. So simply banning homework would mean that any particularly gifted or motivated pupils would not be able to benefit from increased study. However, at the earliest ages, very little homework should be assigned. The decisions about how much and what type are best left to teachers and parents.

As a parent, it is important to clarify what goals your child's teacher has for homework assignments. Teachers can assign work for different reasons – as an academic drill to foster better study habits, and unfortunately, as a punishment. The goals for each assignment should be made clear, and should encourage positive engagement with academic routines. Parents should inform the teachers of how long the homework is taking, as teachers often incorrectly estimate the amount of time needed to complete an assignment, and how it is affecting household routines. For young children, positive teacher support and feedback is critical in establishing a student's positive perception of homework and other academic routines. Teachers and parents need to be vigilant and ensure that homework routines do not start to generate patterns of negative interaction that erode students' motivation.

Likewise, any positive effects of homework are dependent on several complex interactive factors, including the child's personal motivation, the type of assignment, parental support and teacher goals. Creating an overarching policy to address every single situation is not realistic, and so homework policies tend to be fixated on the time the homework takes to complete. But rather than focusing on this, everyone would be better off if schools worked on fostering stronger communication between parents, teachers and students, allowing them to respond more sensitively to the child's emotional and academic needs. 📌

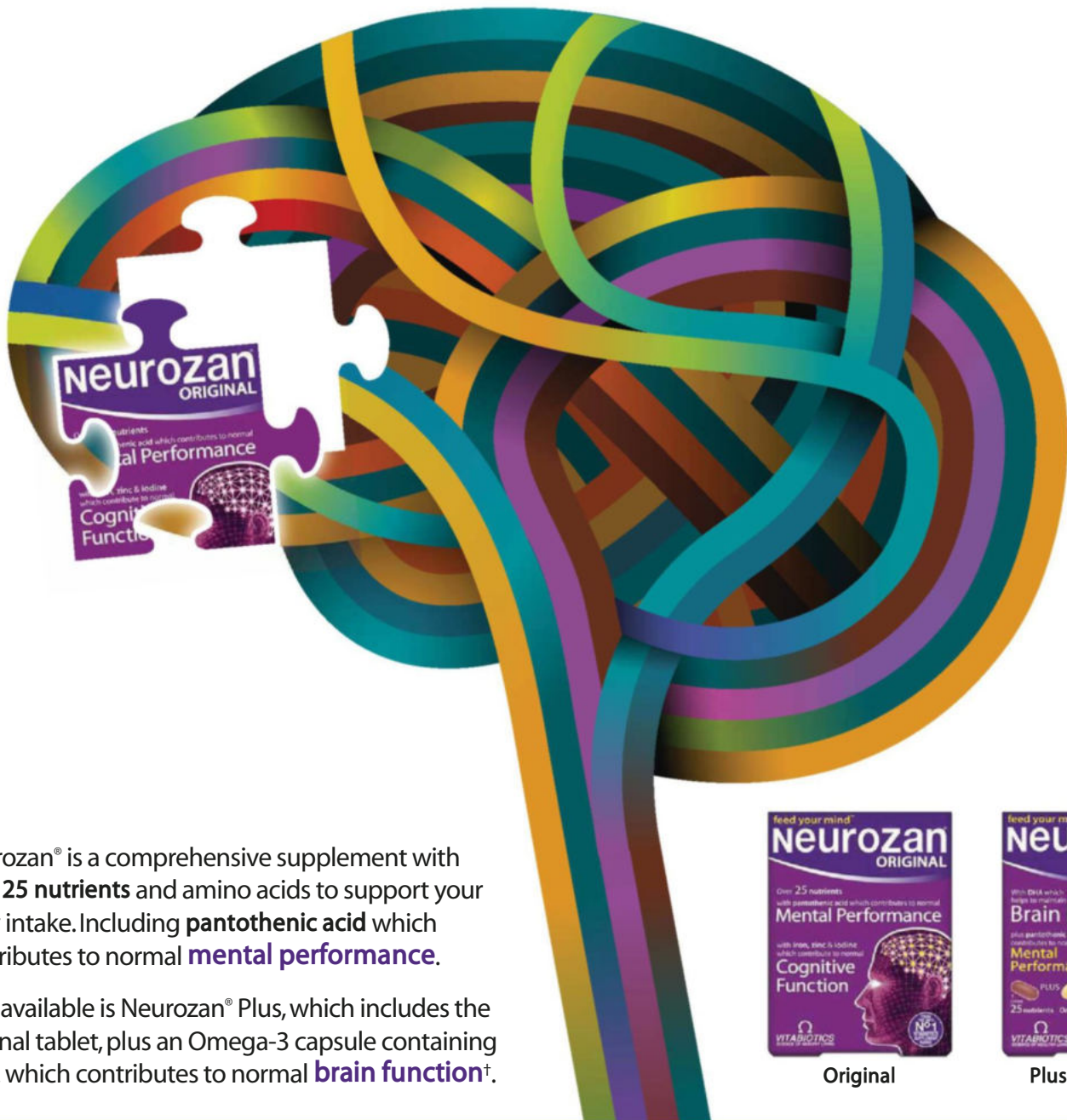
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ROBERT MATTHEWS ON... **LETTING THEORIES GO**

"THE DEATH OF A CHERISHED THEORY COULD GIVE SCIENTISTS THE CLOSURE THEY NEED TO MOVE ON"

People trying to deal with a tragedy often talk of the need for 'closure', some clear-cut event that will allow them to move on. In science, the death of a long-cherished theory can trigger something similar among those who spent years believing in it. But getting scientific closure is much harder than you might think, as an entire generation of theorists are now discovering.

For years they have witnessed the slow, lingering death of a beautiful theory about the nature of the Universe – one so beautiful, in fact, that many thought it would eventually lead to the Theory of Everything.

Known as 'supersymmetry' (or SUSY for short), it's a mathematical property of space and time that leads to deep connections between the two basic types of particle in the Universe: those that form matter, and those that transmit forces between them.

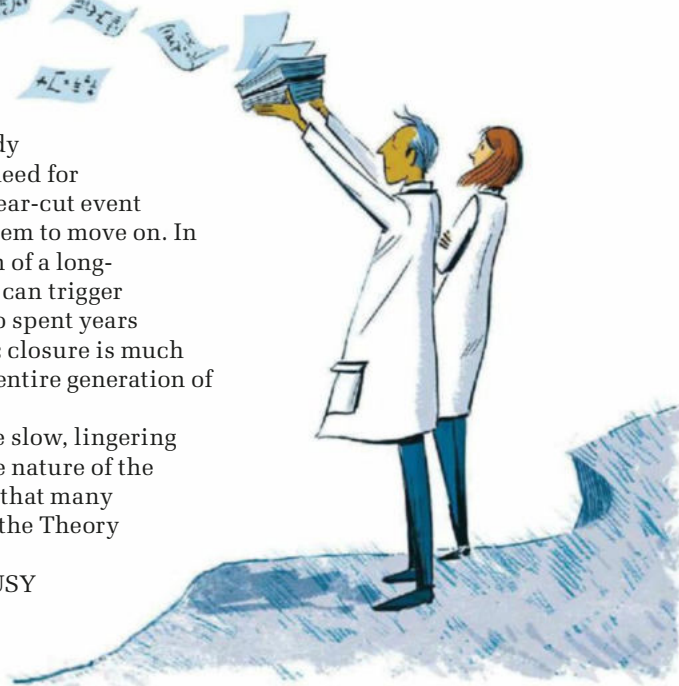
SUSY is just what you'd expect to go into a Theory of Everything, and for over 30 years theorists on the quest for this Holy Grail have put their trust in it.

Meanwhile, experimentalists have been on a parallel quest to put SUSY to the test. They've been looking for so-called 'sparticles' – the counterparts of the known particles predicted by the theory. They've also been encouraged by suggestions that one of these undiscovered sparticles – the neutralino – may be the mysterious 'dark matter' lurking in the Universe.

Yet for all the excitement, SUSY appears to be a beautiful idea that the Grand Designer just ignored. There were high hopes that sparticles would be found in experiments at the Large Hadron Collider (LHC), but so far experimentalists there have found zilch. Those trying to detect dark matter have also found nothing.

Or at least, nothing so far. Some theorists insist it's too early to throw in the towel, and are working on tweaks to the basic idea of SUSY to patch it up and keep it going.

But others see this as pretty desperate, and are insisting it's time to move on. Clearly, what both sides need is closure.



Ideally, of course, closure would take the form of a press conference at the LHC, where the experimentalists announce the exciting discovery of the first supersymmetric particle – preferably the neutralino.


What's never going to happen, though, is what many regard is the hallmark of science: an announcement that SUSY has been proved false. The idea that scientific theories can always be falsified is only ever taken seriously by those who know little

about how science really works.

This idea of falsification was popularised by the philosopher Karl Popper in the 1960s. But it had already been debunked by, unsurprisingly, a real scientist named Pierre Duhem years earlier. Duhem pointed out that ailing scientific theories can always be propped up by blaming, say, dodgy data or inventing some tweak or other.

So if lack of hard evidence can't bring closure for SUSY, what can? Oddly, it might boil down to some bottles of booze. Over the years, some of the leading advocates of SUSY have made bets with sceptics that they would be proved right by a certain date. Those bets are now coming due, and some theorists have started handing over expensive bottles of cognac.

The turning point may come when American physicist David Gross, the Nobel prize-winning theorist and staunch SUSY fan, concedes a bet he made with Ken Lane back in 1994, to buy a posh meal at a

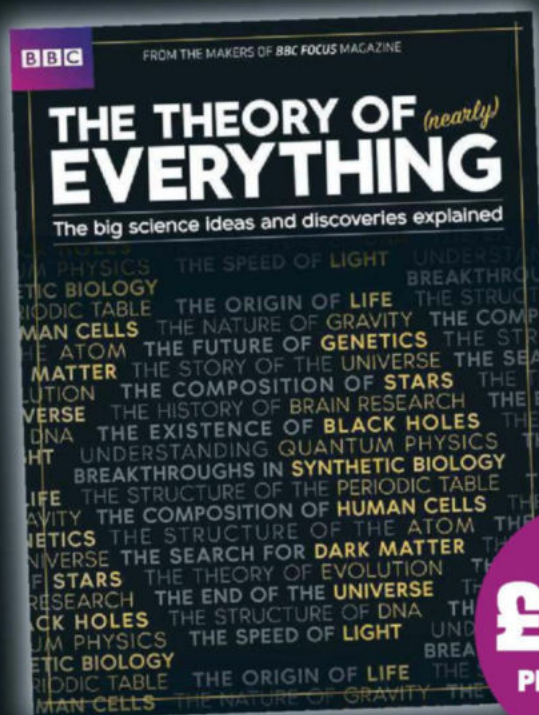
swish restaurant. It will cost him a few hundred dollars and a dented ego. But it could give a whole generation of theorists the closure that they need to move on, so they can start looking for the real keys to the cosmos. 

Robert Matthews is visiting professor in science at Aston University, Birmingham.

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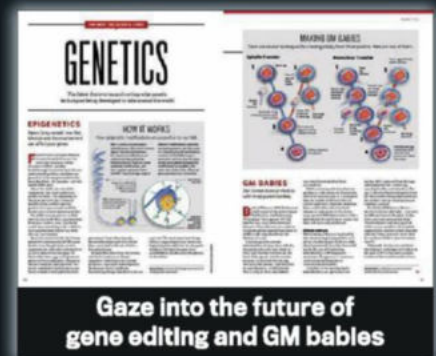
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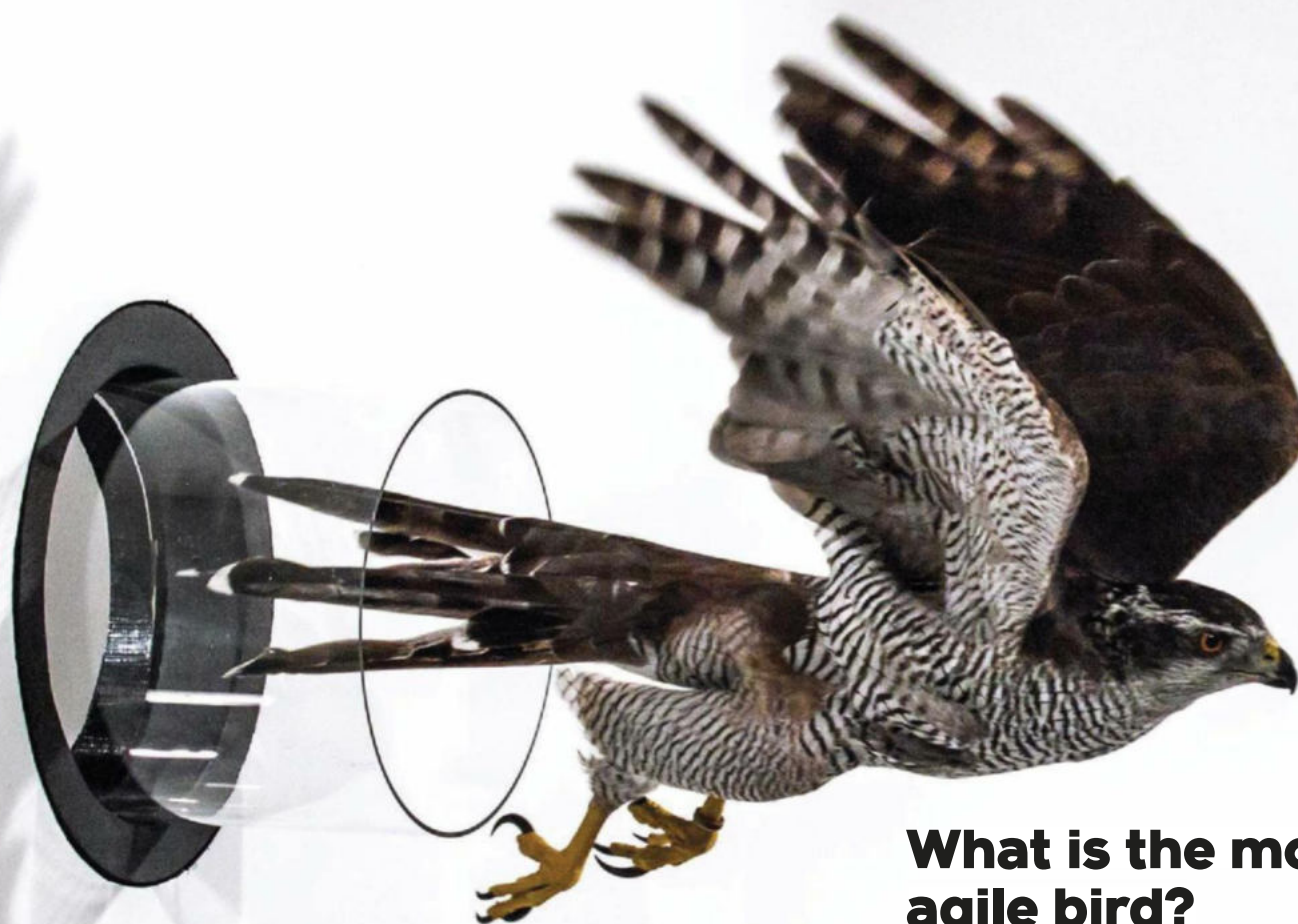


PROF ROBERT MATTHEWS
Physicist,
science writer

YOUR QUESTIONS ANSWERED

JANUARY 2017

EDITED BY EMMA BAYLEY



What is the most agile bird?

RACHEL SANCHEZ, MANCHESTER

The masters of low-speed aerobatics are the hummingbirds, which can hover with millimetre precision, and fly sideways or backwards. But in the avian Olympics, the slalom medals are all won by woodland raptors such as the northern goshawk. Despite having a wingspan of over a metre, these birds can chase prey at up to 60km/h while weaving through dense forest. **LV**

Eat your heart out, Tom Cruise, the northern goshawk outstrips your aeronautical tomfoolery



Why are raspberry drinks blue?

PHIL RIPPON, CARDIFF

In the 1950s, raspberry-flavoured foods were coloured dark red using a dye called amaranth. This later turned out to be carcinogenic and was banned in the US. Food manufacturers started using the bright blue dye instead, partly because it helps to distinguish it from cherry or strawberry flavours, but also because children seem to like brightly coloured foods. **LV**



Why are some people more easily distracted than others?

CALLUM MILNE, GLOUCESTER

Differences in attention span are a result of genes and environmental experiences. These influences can impact upon brain development and functioning, making it more difficult for one person to pay attention than another.

A distinction can also be made between 'bottom up' and 'top down' attention. The former involves us becoming distracted by a salient feature in our environment, such as a bright light. The latter is when we focus on something based on our internal goals – we may give a boring document our full attention because we want to pass an exam. These types of attention share some underlying mechanisms, with the frontoparietal network of the brain important for both, for example. **AGr**



Nope, this isn't Tim Burton's latest creation, it's a uniform that was worn by 17th-Century plague doctors

Could the Black Death happen again?

CHRIS MACKIN, NORTH YORKSHIRE

No. Bubonic plague killed at least one-third of the population of Europe between 1346 and 1353. But that was before we knew it was caused by the bacterium *Yersinia pestis*. Bubonic plague does still occasionally occur

in small flare-ups of a few dozen cases, but we have antibiotics to treat it now. Plus, better hygiene makes it very hard for a disease spread by flea bites to become a global pandemic again. **LV**

IN NUMBERS

53

The percentage of a chromosome that's made up of DNA. The other 47 per cent is a sheath enclosing the genetic material.

3,300

The grip strength, in newtons, that a 4kg coconut crab can exert with its claw.

204

The number of cubic metres of soil dug up each year by a single echidna as it forages for insects.

What is tidal locking?

DENNIS LUND, SALISBURY

Tidal locking is the phenomenon by which a body has the same rotational period as its orbital period around a partner. So, the Moon is tidally locked to the Earth because it rotates in exactly the same time as it takes to orbit the Earth. That is why we only see one side of the Moon. If both bodies are of comparable size and are close together, both bodies can be tidally locked to each other – this is the case in the Pluto-Charon system. Tidal locking is a natural consequence of the gravitational distortions induced by a body on another. **AGU**



"I wish this was a waterbed..."

How do fish sleep?

MALGO CHRZAN, LONDON

It's hard to say if fish sleep like we do. Most can't close their eyes and have no neocortex, which is the part of the mammalian brain that displays distinct patterns of activity during sleep. Even so, many fish settle down for the night on the seabed. Parrotfish sleep inside a mucous bubble, perhaps

so predators can't smell them. At night, zebrafish float in the water column and are difficult to rouse. Some fish never seem to sleep, including blind cave fish and fish swimming in shoals through featureless water. It could be they receive limited sensory input and their brains don't need to rest. **HS**

THE THOUGHT EXPERIMENT

HOW MUCH WOULD YOU HAVE TO DIG TO ALTER EARTH'S ORBIT?



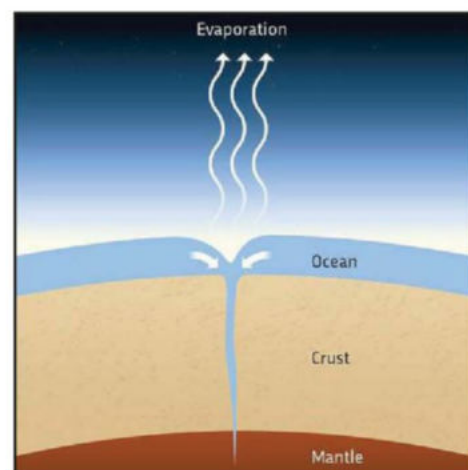
1. EARTH MOVING

Digging a hole into the ground doesn't apply any net force on the Earth. But as you remove soil from the hole and pile it up into a heap, you are very slightly shifting the centre of mass of the planet. This will cause it to wobble a little as it rotates. The effect is very small, however.



2. SOIL LAUNCHING

If you fling each spadeful of soil into space, then you could apply a net force to the planet. You'd need to throw it hard enough to achieve escape velocity, but every billion tonnes you throw over your shoulder would change Earth's orbital velocity by two nanometres per second.



3. SEA BOILING

Alternatively, you could dig a hole at the bottom of the Pacific Ocean deep enough to drain all the water down into the mantle. If this boiled all the ocean into steam and jetted it into space, it might add an extra 1.5km/h to the Earth's normal orbital speed of 108,000km/h.

COMMON RADIOACTIVE FOODS PER KG



1. Brazil nuts

pCi* per kg: 12,000
pCi per serving: 240



2. Butter beans

pCi per kg: 4,600
pCi per serving: 460



3. Bananas

pCi per kg: 3,500
pCi per serving: 420



4. Potatoes

pCi per kg: 3,400
pCi per serving: 850



5. Carrots

pCi per kg: 3,400
pCi per serving: 255



6. Red meat

pCi per kg: 3,000
pCi per serving: 240



7. Avocados

pCi per kg: 2,500
pCi per serving: 420



8. Beer

pCi per kg: 390
pCi per pint: 222



9. Water

pCi per kg: 170
pCi per pint: 100



10. Peanut butter

pCi per kg: 120
pCi per serving: 3.6

* pCi = picocurie



Why does rubber have high friction?

HARPER X, DUBLIN

Despite decades of research into the frictional properties of rubber by tyre manufacturers, the precise causes of the 'stickiness' of rubber are still the subject of argument. Current theories suggest that when rubber moves over

smooth surfaces, it's the molecular forces between the two that are the main cause of friction. But when the surface is rough, it's the deformation of entire molecular layers of rubber that's the chief cause of friction. **RM**



How long can a germ survive on a doorknob?

MAX E JONES, USA

On a hard, non-porous surface like a door handle, most viruses are destroyed within 24 hours. The survival time for bacteria is more variable. *Salmonella* only lasts four hours, but MRSA can last several weeks and *C. difficile* has been found to survive for up to five months. On clothing or skin, the survival time is roughly halved. This may be because these surfaces dry out more quickly, or because they interfere with the bacteria's ability to produce protective biofilms. **LV**

IN NUMBERS

85

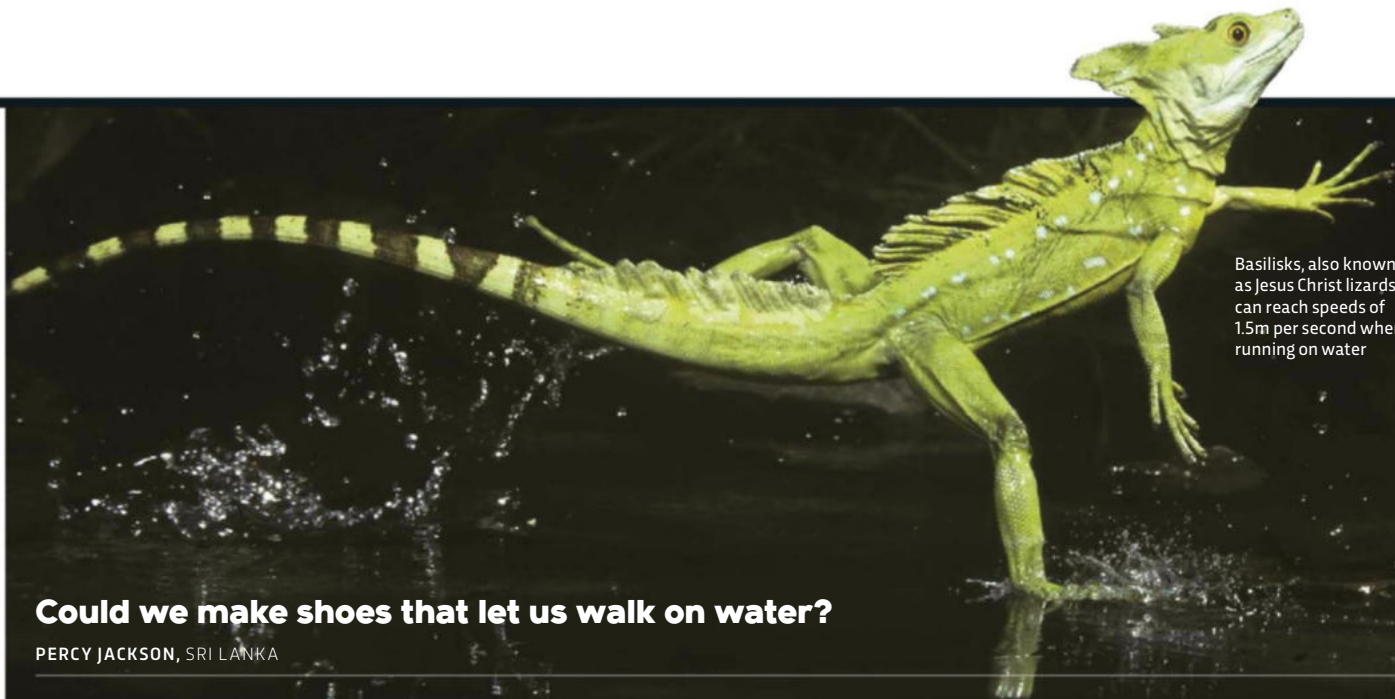
The percentage of European urbanites exposed to harmful particulate matter.

1,445

The number of new viruses discovered in invertebrates as part of a recent study.

60°

The amount by which Pluto may have tilted, due to its heavy, ice-filled, heart-shaped basin.



Basilisks, also known as Jesus Christ lizards, can reach speeds of 1.5m per second when running on water

Could we make shoes that let us walk on water?

PERCY JACKSON, SRI LANKA

Shoes that provide enough buoyancy to keep you afloat are simple but bulky. You're really just cutting a raft in half and standing with one foot on each half. Leonardo da Vinci sketched an idea for this in the 15th Century and it is a common school project for physics students. The hard part is designing shoes that provide enough traction to let you push against the water, without being so cumbersome that you exhaust yourself after a few steps. But skipping over the surface, like the basilisk lizard does, is much tougher. A 1996 study at Harvard

discovered that the lizard strikes the water hard enough with each step that it creates a bubble of air surrounding each foot, and then pulls its feet up again fast enough to clear the surface before the bubble collapses, which minimises drag. When you scale the forces up to human size, you would need to run at over 100km/h (62mph) to pull this off. At least in Earth's gravity. A 2012 study at Rome's Laboratory of Neuromotor Physiology found that if you wore flippers, and could find a suitable pool, you could run on water on the Moon. **LV**

QUESTION OF THE MONTH

What colour is the sky on an exoplanet?

ALEX PACYNKO, BRISTOL

The colour of the sky on an exoplanet depends on many things: the pressure, density and chemical composition of its atmosphere, the presence or absence of dust particles, vapour and clouds, the spectrum of the planet's parent star, as well as the size, composition, colour and even biology of the planet itself. On Earth, the sky is predominantly blue but becomes orange or red near the setting or rising Sun. On Mars, the opposite is true. These differences are mainly due to which compounds or gases are scattering and absorbing the sunlight. Scattering is the predominant factor in most atmospheres and since molecules scatter short wavelengths best and longer wavelengths the least well, this often results in blue skies. But large amounts of dust will lighten and sometimes redden sky colours. Mars' atmosphere appears red because of the presence of iron oxide-rich dust particles. High-pressure atmospheres would be much lighter than lower pressure ones and could appear completely white or yellow. Given the number of factors involved it isn't unreasonable to suppose that exoplanet skies could be any colour at all – from blue or cyan, through green and yellow to red, orange and purple – even brown and white are possible. **AGU**

WINNER!

Alex Pacynko wins a set of AfterShokz Trekz Titanium headphones (£109.99, aftershokz.co.uk). The innovative wireless headphones deliver music using bone-conduction technology, ensuring your ears remain open to your surroundings.



How old is water?

PAUL LESLIE, CHELMSFORD

As Earth was intensely hot following its formation 4.6 billion years ago, little of today's water is likely to date back that far. Instead, it's thought to have arrived later, in collisions with objects from elsewhere in the Solar System. Comets were long thought to be the most likely source, but data sent back from the recent Rosetta mission has confirmed suspicions that these 'dirty snowballs' contain water with a mix of isotopes different to water found on Earth. So attention has now switched to so-called Kuiper Belt Objects (KBOs) orbiting far beyond Neptune. Studies of these asteroid-like objects have revealed the presence of water, and they are now suspected of having delivered it to Earth when swarms of them smashed into our planet around 3.8 billion years ago. **RM**

Kuiper Belt Objects are the prime suspects for delivering water to Earth



Can coral reefs recover from bleaching?

SALLY MORRISON, LEICESTER

Coral bleaching occurs when warmer sea temperatures cause coral to expel the tiny algae that live in their tissues. Without these algae, corals are more susceptible to disease, with impaired growth and reproduction rates. If increased temperatures were short-lived, surviving corals can sometimes regrow their algae within a few months. When bleaching is localised, healthy coral nearby can also help repopulate the area. But in instances of more severe, extensive or repeated bleaching events, or when additional stresses such as pollution or ocean acidification come into play, large swathes of coral may die and recovery can take decades. **AC**

HEAD TO HEAD



COW'S MILK* (PER 100ML)

ALMOND MILK (PER 100ML)


35	CALORIES	13
<0.1g	SATURATED FAT	0.1g
3.4g	PROTEIN	0.4g
0.1g	SALT	0.13g
trace	VITAMIN D	0.75mcg (7.5% RDA)
120mg (12% RDA)	CALCIUM	124mg (12% RDA)

Almond milk and skimmed cow's milk are nutritionally very similar. That's because almond milk is a synthetic product designed to resemble milk. The fat and salt content are virtually identical, and while cow's milk has

more protein, it's still too little to make much difference to your diet. As well as being suitable for lactose-intolerant people, almond milk is slightly healthier though because it contains vitamin D, which cow's milk does not.

* Skimmed





Japan's largest coral reef, Sekiseishoko, is starting to bleach and die because of higher sea temperatures



Why do our eyes move when we sleep?

ELENA HOLDEN, LONDON

Our sleep can be split into two main stages – rapid eye movement (REM) and non-rapid eye movement (NREM) sleep. It is during REM sleep that our eyes dart about. This is also the stage of sleep during which we are most likely to dream. The movement of our eyes is due to specific brain activity that is characteristic of this stage of sleep. Research suggests that eye movements may allow us to change scenes while we are dreaming. Scientists found that the neuronal activity following eye movements during REM sleep resembled that seen when people are shown or asked to remember an image when they are awake. **AGr**



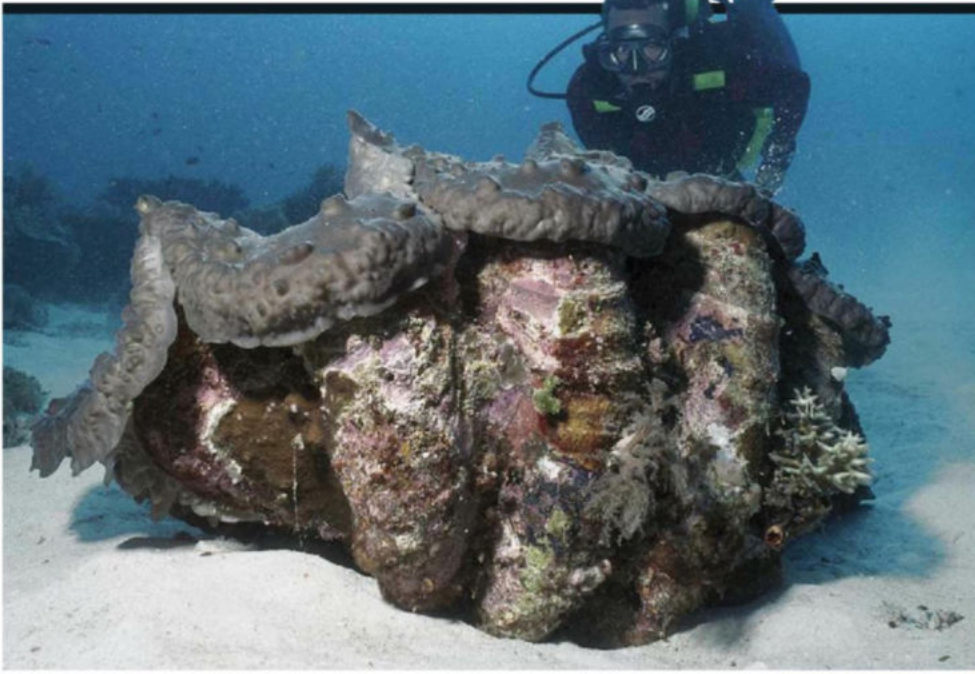
Why can't we regrow teeth?

PETER RICHARDS, LEAMINGTON SPA

Your baby teeth and adult teeth all began developing before you were even born. Our DNA still contains all the genes that sharks use to grow their endless conveyor belt of replacement teeth, but in humans these genes are deactivated by the 20th week of foetal development. The advantages of keeping the same teeth through adulthood is that they can be securely anchored in the jawbone, which allows us to chew tough plants and grains. **LV**

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What creature makes the biggest seashell?

CHRIS HARRIS, LEEDS

Seashells are the exoskeletons of animals called molluscs, including snails, nautiluses, mussels, scallops and oysters. The biggest are giant clams, *Tridacna gigas*. Their twinned shells can grow to well over a metre across and tip the scales at 200kg, the same as two newborn elephants. Giant clams, like all

shell-making molluscs, sculpt their protective homes from calcium carbonate and gradually expand them throughout their lives. They inhabit coral reefs and can live for at least a century. Demand for their meat as a delicacy in many countries is making them vulnerable to extinction. **HS**

Is Antarctica melting?

RICK WRIGHT, DURHAM

Antarctic sea ice undergoes an annual cycle of freezing and melting, reaching its maximum extent in October and then melting. In the past few decades, the maximum amount of Antarctic sea ice has increased slightly, but on land it's a different story. While a few areas of the frozen continent's gigantic ice sheet have been growing, overall Antarctica is losing ice, with glaciers in West Antarctica undergoing the most rapid melting. Ice shelves fringing the Antarctic land mass, where land ice meets the ocean, are also shrinking. As global temperatures increase, scientists expect to see further melting, contributing to global sea level rise. **AC**



WHAT CONNECTS...

...NUCLEAR WEAPONS AND FINE WINE?

1.



In 1945, the US Army conducted the first nuclear weapons test, as part of the Manhattan Project. Since then, there have been over 2,000 nuclear explosions around the world.

2.

Each nuclear explosion releases several hundred grams of the radioactive isotope caesium-137.

This has a half-life of about 30 years, so it is not normally found in nature.



3.



Caesium-137 dust gets dispersed in the atmosphere and reacts with rainwater to form soluble salts. From there it is absorbed, in tiny quantities, by plants through their roots.

4.

Although it is quite safe to drink, any wine bottled after 1945 has detectable amounts of caesium-137 and this can be used to spot fake bottles claiming to be much older.





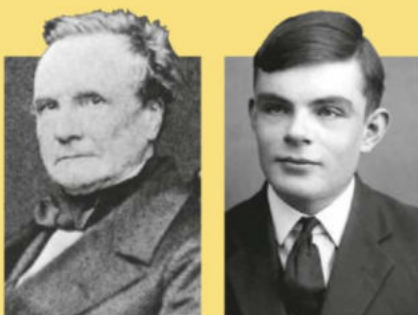
WHAT IS THIS?

Sky high

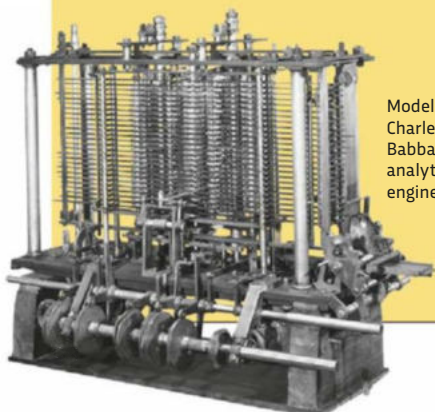
Brighton's British Airways i360, designed by the creators of the London Eye, is the world's tallest moving observation tower. Visitors climb aboard the glass pod, seen here, then ascend 138m where they can enjoy panoramic views across Brighton and the South Downs. A total of 1,336 bolts, weighing a whopping 30 tonnes, hold the i360 together. The structure has a diameter of a svelte 3.9m, earning it a Guinness World Record as the world's most slender tower.

WHO REALLY INVENTED?

THE COMPUTER

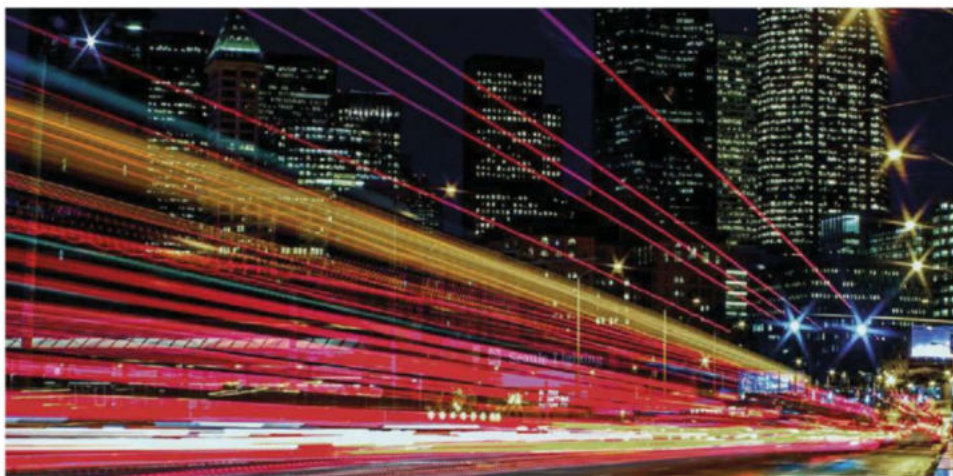
CHARLES
BABBAGEALAN
TURING

Computers are far more than ultra-fast number-crunchers. Crucially, if given a new set of instructions, a computer's processor and memory can – in principle, at least – do anything from word-processing to flying a plane. Credit for being the first to consider building so versatile a device goes to the British mathematician Charles Babbage, who in 1834 began drawing up plans for what he called the 'analytical engine'. His dream was to create a device whose gears, rods and wheels could be arranged – programmed – to perform a myriad of tasks from solving equations to composing music. Sadly, only a fragment of this Victorian engineering miracle was ever completed. It took another 100 years before another British mathematician, Alan Turing, revived the idea of a 'universal machine' and investigated its theoretical powers. During WWII, his code-breaking colleagues at Bletchley Park exploited some of these powers. Their electronic device was called Colossus, and it broke Hitler's most secret ciphers. Historians still argue about who built the first genuine computer, but it's generally agreed that engineers in the US and Britain both succeeded in creating electronic machines embodying Babbage's dream by the late 1940s. **RM**

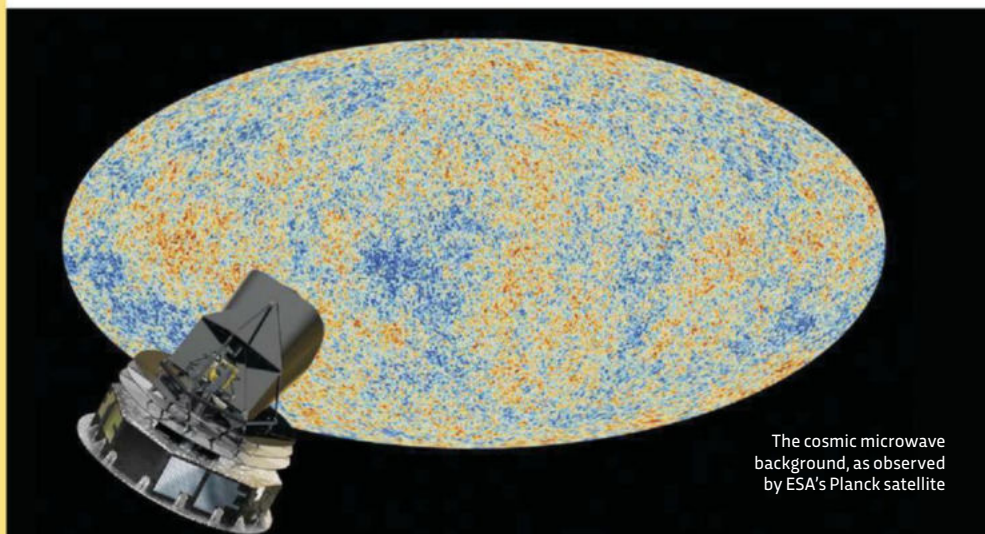
Model of
Charles
Babbage's
analytical
engine

Why is everything in motion?

OFOSU ANTWI KENNETH, GHANA



Everything in the Universe is in motion because forces exist in the Universe. The gravitational force and the electromagnetic force ensure large objects are in motion while the weak and strong nuclear forces ensure the quantum world is constantly in motion. If there were no forces, there would be no motion. The question of why there are forces in the Universe is currently unanswerable by science. They appear to be fundamental and demonstrable facts but there may not be an ultimate reason for their existence, just as there may not be a root cause for the existence of the Universe itself. **AGU**

The cosmic microwave
background, as observed
by ESA's Planck satellite

Will the cosmic microwave background disappear?

JAMIE EDWARDS, ESSEX

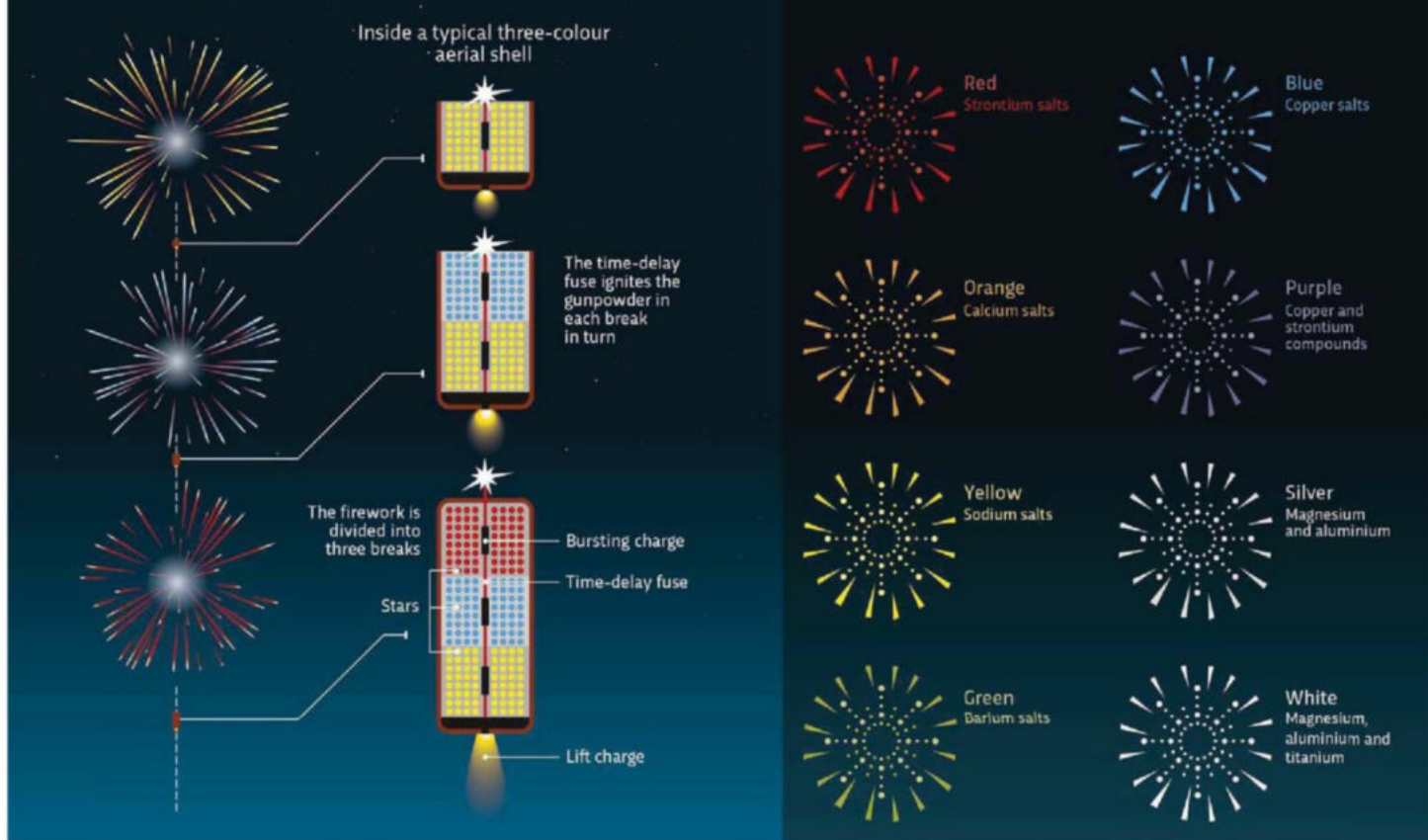
Yes. This relic radiation left over from the Big Bang is being increasingly redshifted as the Universe expands. So its energy is being constantly diluted. After another few trillion years, the current cosmic microwave background will have redshifted into insignificance

and will no longer be detectable. In this far-flung future, the Universe will have expanded so much that even the closest galaxies will be well beyond our sight. At this time, there will be no visible evidence that the Universe is expanding or that there was ever a Big Bang! **AGU**

HOW IT WORKS

FIREWORKS

When the firework is lit, a fuse ignites a pouch of black powder in the base that launches the firework into the air. A second 'time delay' fuse ignites, leading to the centre of the firework. The chemicals in the 'stars' are the magic of the firework, creating all the dazzling colours.



Why do some planes leave trails and others don't?

PEARL GOODWIN, LEWES

Technically known as contrails, these white trails are created from water vapour produced by the combustion of fuel in aircraft engines. At their cruising altitude of 10,000m, temperatures are around -55°C. As it's so cold, the water turns to ice particles, but how long they remain visible depends on humidity. If the air is relatively humid, the contrails will grow and remain visible long after the aircraft has disappeared. **RM**



NEXT ISSUE:

What causes middle-age spread?

Why do cats have whiskers?

Can we unlearn things?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda



**Christopher
Ward**

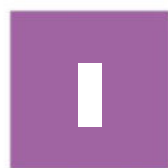
The New C65
Trident Vintage 38mm

christopherward.co.uk



ROBIN INCE ON... **HABITS**

"IT TAKES AN AVERAGE OF 66 DAYS TO FORM A NEW HABIT. THERE ARE NO QUICK FIXES"



have successfully given up smoking four or five times. My most recent attempt is the best so far: it's now at least six years since I last

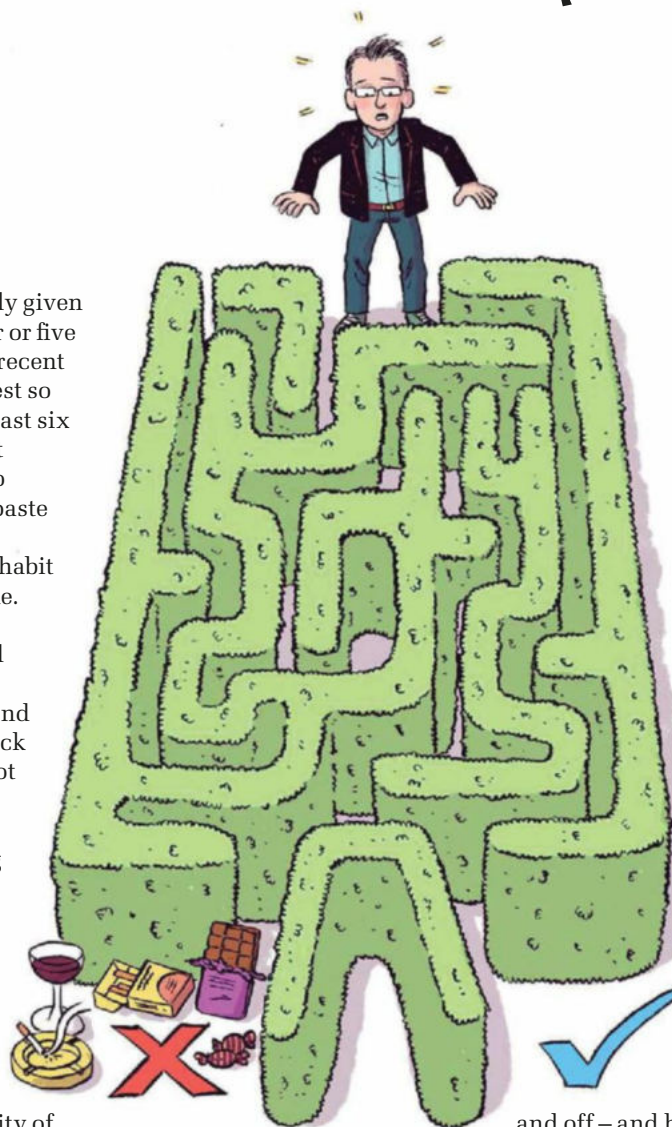
puffed on a cigarette (and tried to disguise the fact by eating toothpaste on the walk home).

Unfortunately, removal of one habit usually creates time for a new one. During the writing of this brief column, I have checked on social media four times. I am a rat mindlessly hitting a pedal over and over again in the belief that a snack lozenge of gossip or fact will shoot out in 140-character form.

Habits aren't always bad. In fact, they can be useful, stopping us crashing into central reservations or being run over as we cross the road. It's estimated that around 40 per cent of our daily activities are performed in almost the same situations every day.

According to psychologist Prof Wendy Wood at the University of Southern California, as we learn a new habit, the information shifts from a decision-making part of the brain (the basal ganglia) to an automatic process that we're largely unaware of (the sensory-motor system). So how can we go about shifting those bad behaviours?

Wood investigated this using stale popcorn. After checking that people preferred fresh popcorn to stale, she found that cinemagoers who have a habit of eating popcorn at the movies ate just as much stale popcorn as fresh. As long as the environmental cue is there, the habit is maintained. It's the same problem with giving up smoking – a battle must be fought every time you find yourself in one of your old smoking haunts. Wood suggests that habitual loops can be broken by altering our environments and disrupting the familiar cues, perhaps by changing where we take our work breaks.



Fortunately for those trying to kick bad habits, a study by neuroscientists at the Massachusetts Institute of Technology has shown that not all of our rational brain is switched off when we perform habitual behaviours. The team trained rats to run a T-shaped maze, prompting them to turn left or right at a junction. The rats' reward for turning left was some chocolate milk, and even when this treat was laced with nausea-inducing lithium chloride, they still continued to turn left. The rats had developed a habit. What's interesting is that the researchers could break this habit by inhibiting the rats' infralimbic cortex, which is an area of the prefrontal cortex (part of the brain's planning centres). This suggests that this

region of the brain is responsible for turning habits on and off – and habits might not be as inflexible as often thought.

As for those who are trying to make a new habit: yes, I know you've joined a gym, but you have to be prepared to put the time in. According to researchers at University College London, it takes an average of 66 days to form a new habit. There are no quick fixes: tenacity, backed by the knowledge that the brain can change, is the key.

Let's see how long it takes me to break my social media addiction and create my new habit of searching for chocolate milk in mazes. I'd better remember not to tweet while I'm at Hampton Court #nochocolatemilkin thistudorhedge. 🍫

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage* bbc.in/1Lxp3QR

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JANUARY 2017

EDITED BY JAMES LLOYD



PHOTO: MATTHEW GORDON / BBC

01

SPY IN THE WILD
BBC ONE, JANUARY.

MEET THE SPYCREATURES

Well, wouldn't you be surprised too? A grey langur does a double take as it meets its animatronic equivalent in Rajasthan, India.

This candid shot was taken during filming of the BBC's new five-part series *Spy In The Wild*, a follow-up to previous 'spy' series including *Spy In The Huddle* and *Spy In The Pod*. This time around, *Spy In The Wild* sees over 30 robotic animals being released into habitats around the world.

There are animatronic fish, birds, mammals and reptiles, from tiny SpyCrocHatchlings to a full-size SpyOrangutan. Made to look and smell as realistic as possible, and even to move just like the real creatures they represent, the SpyCreatures allow us to get remarkably close to wild animals, infiltrating their most intimate moments and witnessing some surprisingly human-like behaviour.

Turn over for an interview with one of the show's creators. ➤



Q&A: ROB PILLEY

Series producer for
Spy In The Wild



How were the creatures made?

Each spy animal has a bare metal skeleton, a chassis, and a complicated system of servos and motors that allow it to move. Most of the skins are made of latex, and the fur is generally acrylic. For the birds, we typically used dyed goose and chicken feathers, each one having to be individually punched into the skin in the correct position. We also had to make some of the animals smell like the real thing by rubbing poo all over them!

Which was the most challenging SpyCreature to build?

The SpyCrocodile: it has 26 individual motors and an onboard computer to allow it to walk realistically, with the limbs, spine, pelvis and tail all moving simultaneously. It took two people to operate it in the field, constantly adjusting its gait as it moved over different terrains.

Who were they made by?

There's no one person out there who is able to build spy animals this detailed, so each robot was a collaboration between a team of precision engineers, animatronics specialists, programmers, model makers and make-up artists from all over the world.

Was the entire series filmed from the SpyCreatures' perspective?

No, in order to make these films emotionally rich, we needed a range of viewpoints. For each shoot, we'd have potentially 10 individual cameras: the SpyCreatures themselves, peripheral spy cameras such as 'log cams' and 'boulder cams' and then one or two natural history camerapeople too. You need all of these elements to tell the

story – it would be exhausting to see everything from the SpyCreatures' point of view only.

Can you pick out a couple of personal highlights from the series?

To be up close and personal with these animals is something else. To be gently picked up in the mouth of a crocodile because she thinks you're one of her babies is a unique moment in time!

SpyTortoise in particular had an eventful journey. He met some chimps, who pulled him up a tree and used him as a pillow. He eventually got squashed by an elephant, but not before he'd met a real tortoise and got involved in some romantic antics...

What was your favourite part of making Spy In The Wild?

We had over 8,000 hours of material in total, and when you go through it, you see the same animals again and again. So you start to get to know them, and you realise how their emotions, their relationships, and their mischievous sides are so incredibly human-like. That was one of the pinnacles of the series for me, to step into the world of these animals like never before.

SPIES IN THE WILD

Meet some of the stars of the show...



SPYORANGUTAN...

learns how Is from wild orangutans in Borneo.

SPYWARTHOG...

makes some unlikely mongoose friends, who offer him their grooming services.



SPYPUFFERFISH...

spies on young dolphins who are 'getting high' by chewing on real pufferfish.



SPYOSTRICHCHICK...

witnesses the plight of a daring female ostrich as she lures lions away from her chicks.



SPYTORTOISE...

is adopted by a curious chimpanzee, and finds himself in the middle of a love tryst with another tortoise.



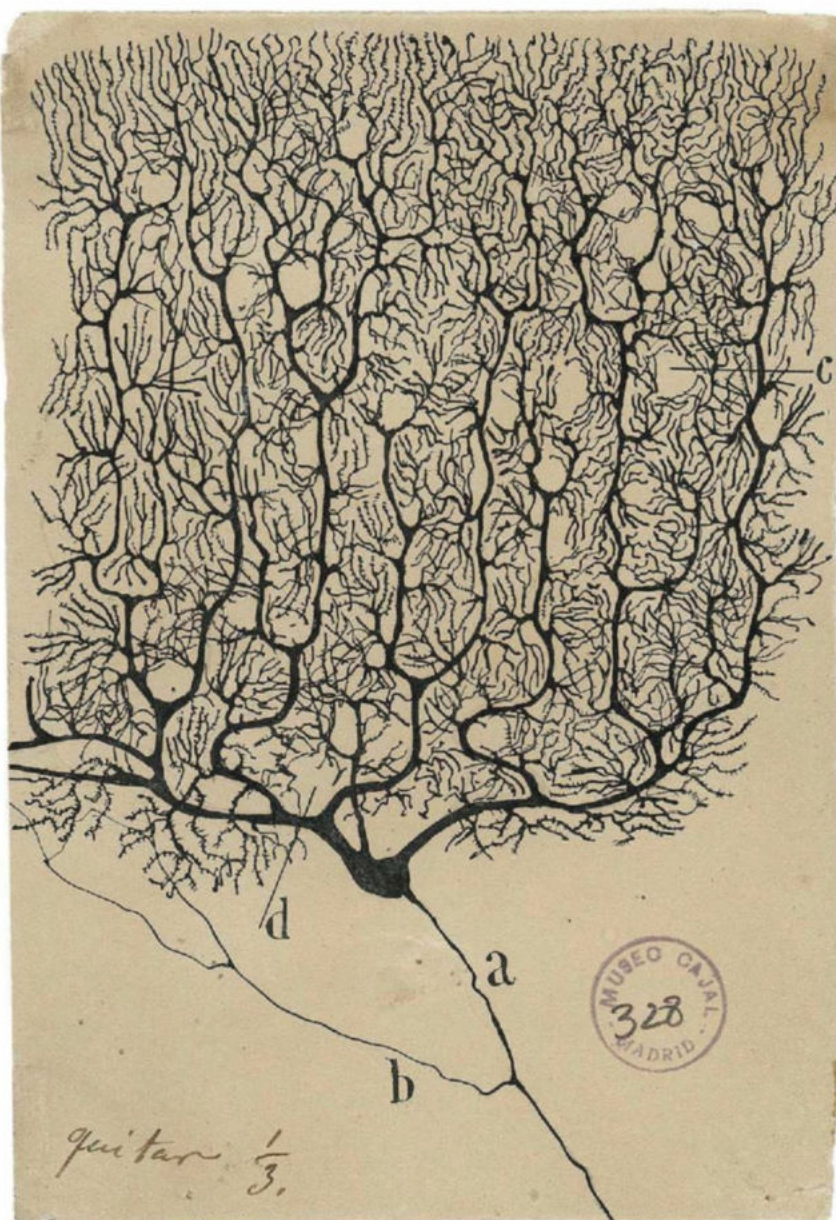
02 EXPLORE THE BEAUTIFUL BRAIN

**THE BEAUTIFUL
BRAIN: THE
DRAWINGS OF
SANTIAGO
RAMÓN Y CAJAL**
OUT 17 JANUARY
(£25, ABRAMS).

Long before MRI and CT scanners arrived on the scene, a Spanish pathologist called Santiago Ramón y Cajal (1852-1934) was studying the brain by examining thin, chemically stained slices under a microscope. Viewed by many as the creator of modern neuroscience, Cajal produced nearly 3,000 drawings, making the fundamental observation that the brain is made up of individual nerve cells, or neurons.

This new book gathers together over 80 of Cajal's most important illustrations, including the intricate Purkinje neuron seen here. With their elaborate, tree-like structure, these are some of the largest, most distinctive cells in the human brain. They're located in the cerebellum, a structure that plays a central role in motor control. The clarity and elegance of Cajal's drawings means they're still relevant today.

BELOW: Santiago Ramón y Cajal
LEFT: His drawing of the Purkinje neuron
BOTTOM: A modern image of the Purkinje neuron, taken with a microscope

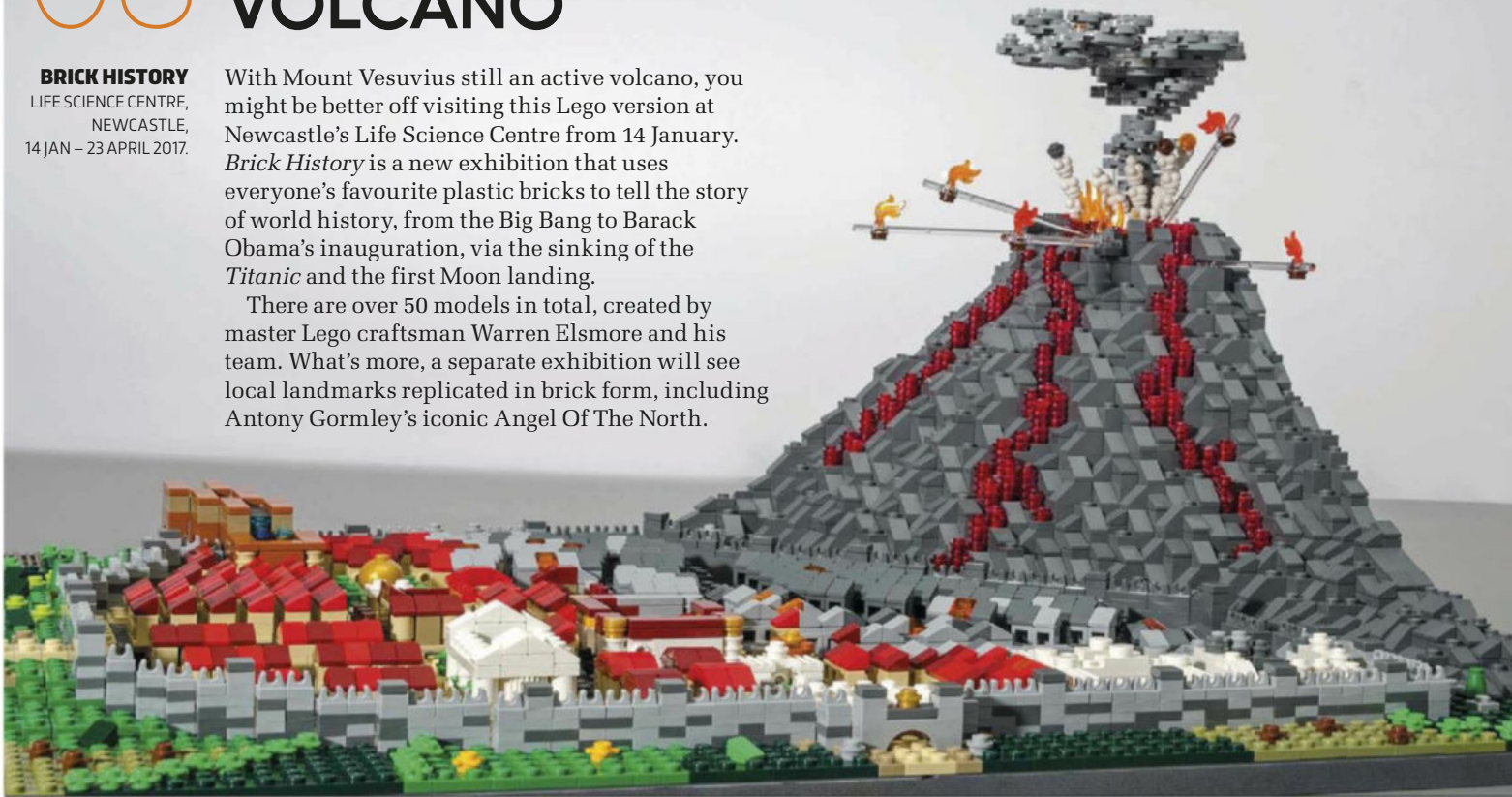


03 SEE A BRICK VOLCANO

BRICK HISTORY
LIFE SCIENCE CENTRE,
NEWCASTLE,
14 JAN – 23 APRIL 2017.

With Mount Vesuvius still an active volcano, you might be better off visiting this Lego version at Newcastle's Life Science Centre from 14 January. *Brick History* is a new exhibition that uses everyone's favourite plastic bricks to tell the story of world history, from the Big Bang to Barack Obama's inauguration, via the sinking of the *Titanic* and the first Moon landing.

There are over 50 models in total, created by master Lego craftsman Warren Elsmore and his team. What's more, a separate exhibition will see local landmarks replicated in brick form, including Antony Gormley's iconic Angel Of The North.



04 GET THE KIDS EXCITED ABOUT SCIENCE

BBC TERRIFIC SCIENTIFIC
BEGINS IN JANUARY
BBC.CO.UK/
TERRIFICSCIENTIFIC

With surveys showing that fewer than 15 per cent of 10-14 year olds aspire to become scientists, BBC Learning has launched an 18-month project that aims to bring practical science into every primary school in the country.

The focus of Terrific Scientific is on hands-on, nationwide experiments, backed by interactive webcasts. The first investigation, taking place this month, is centred around the theme of taste. Pupils will be tasked with finding out what percentage of their class are 'supertasters' – people who find bitter tastes more unbearable than others.

There are four more experiments planned in the first phase of Terrific Scientific, from February to June, including an investigation into whether changing the clocks affects sleep patterns, and an audit of the trees in school playgrounds. Schools will be able to upload their results to an interactive map of the UK, and the findings will even feed into real research being carried out by universities around the country.



PHOTO: ALAMY



Tefal

Ideas you can't live without.

COOK4ME connect

Continuing this revolution in home cooking is the Cook4Me Connect. This new one pot wonder allows you to control the device from your smartphone or tablet.

The kitchen appliance comes with 50 pre-programmed recipes (starters, mains and desserts), which include step-by-step guides, detailing the exact ingredients and measurements for each dish, via its built in LED display.

More convenient and versatile than ever, **Tefal's Cook4Me Connect** comes with Bluetooth connectivity and a dedicated app for your smartphone or tablet (**My Cook4Me**, available on Google Play and the App Store). Where you can access a digital library of over 100 recipes that sync straight to the appliance.

This all-in-one pot solution is perfect for families who want homemade quick and tasty meals or those who don't want to spend hours in the kitchen. You can cook an entire meal in just one pot, and enjoy the added benefit of hassle-free cleaning afterwards.

It's also a great assistant for the more insecure cook who still wants to experiment and values the importance of preparing fresh and healthy meals.

With six cooking functions: pressure cook, steam, brown, simmer, slow cook or reheat, it's an excellent time saver too! Most recipes can be cooked in 15 minutes or less!

tefal.co.uk/cook4me-connect

Both of these breakthrough launches took place this year but there's a lot more to come in 2017, as **Dominik Pytel, Groupe SEB Marketing Director** says, "This is our first foray into the world of connected appliances and we have ambitious plans in place to further develop this market in the UK."



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ELIZABETH WHITE SHARES HER FAVOURITE SPOTS IN **BRISTOL**



1 **SS GREAT BRITAIN**

Brunel's historic steamship is now a popular attraction. *Great Western Dockyard, Gas Ferry Road, BS1 6TY* ssgreatbritain.org

2 **ARNOLFINI**

Contemporary arts centre situated on the Harbourside *16 Narrow Quay, BS1 4QA* arnolfini.org.uk

3 **GRAIN BARGE**

Pub and restaurant on a converted barge. *Mardyke Wharf, Hotwell Road, BS8 4RU* grainbarge.co.uk

4 **LIDO**

Refurbished pool, restaurant and spa dating back to 1849. *Oakfield Place, Clifton, BS8 2BJ* lidobristol.com

5 **CLIFTON ROCKS RAILWAY**

This water-powered funicular railway is now open to the public on selected days. *Sion Hill, BS8 4DQ* cliftonrocksrailway.org.uk

6 **CLIFTON OBSERVATORY**

Features a camera obscura and access to a cave overlooking the Avon Gorge. *Litfield Road, BS8 3LT*

Bristol has a vibrant, creative and outdoorsy feel. It's a very picturesque city and is perfectly positioned for coastal getaways to Wales, Devon, Dorset and Cornwall – or to pop in and out of London.

Most mornings I go for a run around Bristol's harbourside. There's a huge amount of history there, from engineer Isambard Kingdom Brunel's passenger steamship, the **SS GREAT BRITAIN** 1, to the Underfall Yard. This is one of my favourite spots in Bristol as it's still a working boatyard.

Bristol has some lovely museums and galleries. Last year, the **ARNOLFINI** 2 arts centre hosted a wonderful video installation called *Vertigo Sea* by artist John Akomfrah, a meditation on humankind's relationship with the sea, the slave trade and whaling, featuring some of our BBC Natural History Unit footage.

I own a stand-up paddleboard (SUP) and on summer evenings I often head out on the water with friends, paddling past the M Shed museum, and the fantastic old working cranes, before returning to the **GRAIN BARGE** 3 where we moor up

and enjoy a drink overlooking the water. SUP Bristol runs paddleboarding tours in summer for those who don't have their own – only occasionally does someone actually fall in!

I also enjoy relaxing at the **LIDO** 4 in Clifton. It's an old Victorian swimming pool that has been revamped as a spa. Solar panels take the chill off the water (though it's still pretty nippy in winter!).

Clifton has many other historic sites. Most people have heard of the Clifton Suspension Bridge, but fewer have heard of the **CLIFTON ROCKS RAILWAY** 5, a funicular railway dug into the rocks beside the Avon Gorge. It ran from 1893 until 1934 carrying passengers between Clifton and Hotwells. In WWII, after its closure, it was a secret transmission base for the BBC. Occasionally, the site is open for public visits.

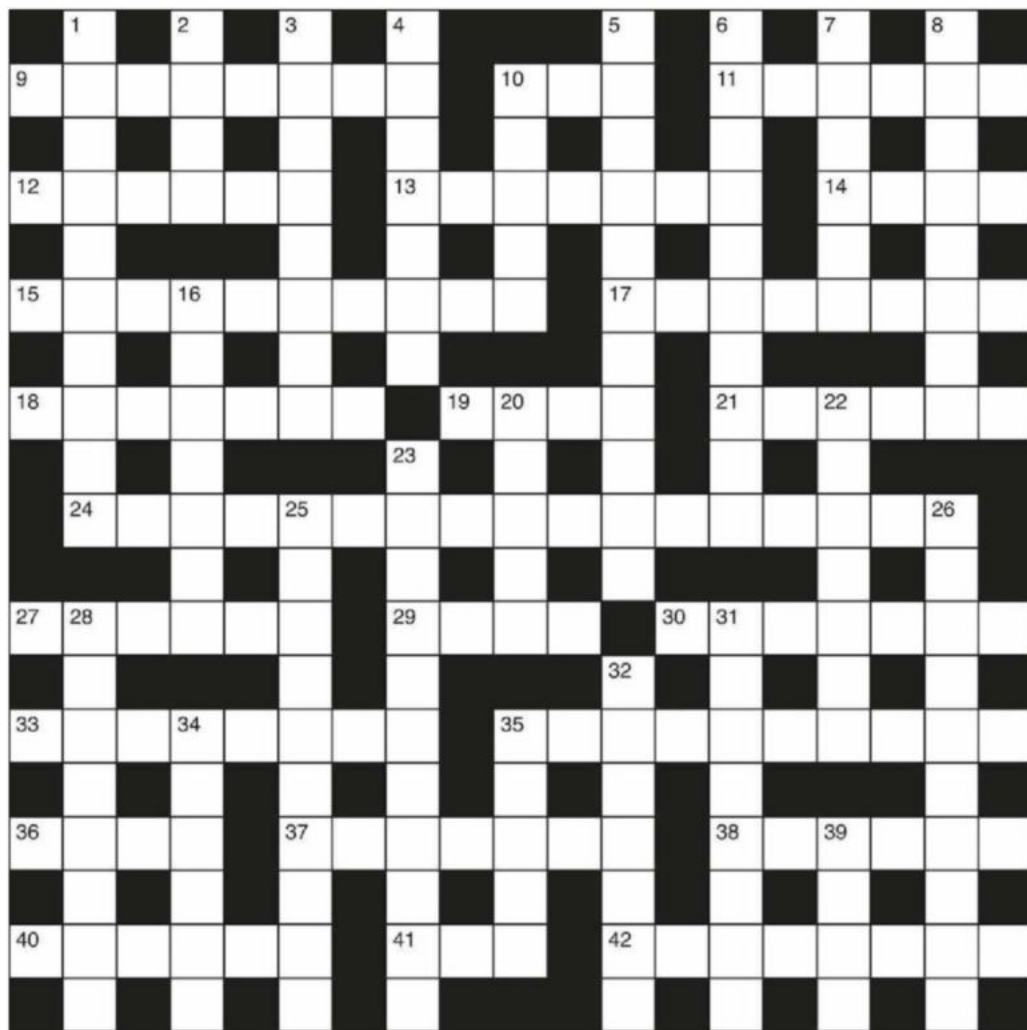
Finally, the nearby **CLIFTON OBSERVATORY** 6 (which features a working camera obscura) is a wonderful place to have an evening picnic – particularly in late summer when the hot air balloons of the Bristol International Balloon Fiesta float across the sky. 7

Dr Elizabeth White is a biologist and filmmaker at the BBC Natural History Unit, and the producer/director of the 'Islands' episode of the recent *Planet Earth II* series.



THE *BBC FOCUS* CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- 1 Old instrument of variable volume (10)
- 2 Attorney volunteers facts (4)
- 3 Producer of French singer went mad (8)
- 4 Vast aim – to improve reversion to former state (7)
- 5 Kitchen utensil somehow generated parking fine (6,5)
- 6 Semiconductor sorts train out (10)
- 7 Real binoculars lacking pigment inside (6)
- 8 Intelligent bishop gets registered during breakfast (8)
- 10 City for cavorting pairs (5)
- 16 Aide got to work at the plant (7)
- 20 Dodge questions about a barrier (5)
- 22 Former spouse has enough for a specimen (7)
- 23 Start to drift if getting tiny bit of deviation (11)
- 25 Large ship that makes for easy conversation (10)
- 26 Preparing salad, tiger is adapted to jump (10)
- 28 Metal has even changed using yeast (8)
- 31 Plates around the garden (8)
- 32 A scoundrel to point to my place of learning (7)
- 34 Editor wrote about valve (6)
- 35 Left coal production in the vicinity (5)
- 39 Call for sign of tree's age (4)

ACROSS

- 9 A bond to money takes shape (8)
- 10 Appearing to have something to eat (3)
- 11 Projection brings comfort (6)
- 12 Its art involved clouds (6)
- 13 Interpretation of victory in sore need of revision (7)
- 14 Snide answer about notion (4)
- 15 Eastern character gets first book on transformation theory (10)
- 17 Terrible anger about old book of spells (8)
- 18 Care about lad wandering in crater (7)
- 19 Offence involving hard part of leg (4)
- 21 Register for a large drink (6)
- 24 Editors – softies – worried about chap having Paget's disease (8,9)
- 27 Hydrocarbon in chalk – a necessity (6)
- 29 Leaf-chewing insect (4)
- 30 Paul's worried about internal bone (7)
- 33 Cite Arab translation of tiny organisms (8)
- 35 Get laconic about producing milk (10)
- 36 Cap on pike distribution (4)
- 37 Worker gets a group of detectives a remedy (7)
- 38 King takes gold ore back to Maori meeting (6)
- 40 Old official finds bit of glass on French article (6)
- 41 Low-flying bird (3)
- 42 Sauce manufactured with special rain (8)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

SCIENCE FESTIVAL GUIDE

Your pick of the best science festivals across the UK happening in 2017



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exhibition@royalsociety.org
www.royalsociety.org/summer

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Rachel Dove "I won the 2015 Flirty Fiction Prima Magazine and Mills and Boon competition. The prize was **£500**, and the chance to work with Mills and Boon on my book which came out in April 2016.

"Also I have three stories in three anthologies with other authors – we've raised almost **£2,000** for cancer charities."

George Stewart "I am delighted to tell everyone that the course is everything it says on the tin, excellent! I have wanted to write for years, and this course took me by the hand and helped me turn my scribbles into something much more professional. I am delighted that my **writing is being published and I am actually being paid**. All thanks to the Comprehensive Creative Writing course."



Katherine Kavanagh "I have been publishing my own website for circus critique. This work has led to recognition in my field, with work offers ranging from writing book reviews for scholarly journals to running master classes for young people. I have had two paid writing residencies at festivals this year and have been employed to write tweets. Payments total **£2575**, plus expenses for travel, tickets to events and payments in kind in the form of review copy books."

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“When the Royal Institution emailed me, I presumed it was a joke – so I deleted it”

Danielle George, professor of radio frequency engineering at Manchester University, talks to **Helen Pilcher** about the importance of tinkering

Where does your interest in science come from?

As a kid, I went through various science ‘phases’. My parents bought me a microscope, then a chemistry set. But it was the next gift – a telescope – that I really loved. I used to get my sisters up at night to watch the lunar eclipses.

What is your area of research?

I engineer tools of scientific discovery. In particular, I design and make devices to pick up signals from space.

So, have you eavesdropped on any little green men?

No, but I helped design the amplifiers and receivers that enabled the Planck spacecraft to detect the leftover radiation from the Big Bang. It’s called the cosmic microwave background radiation and it’s given us the most accurate map of the Universe to date.

What else can you use these sorts of devices for?

All sorts. We’re designing electronic devices that could be ploughed into the soil and then send signals to farmers. They would be able to tell the farmer everything, from which parts of their land need irrigating most, to where the weeds are most likely to grow and when is the best time to harvest their potatoes.

Of what are you most proud?

2014 was a big year for me. My husband calls it ‘the three Ps’. I became a professor, got pregnant and presented the Royal Institution’s Christmas Lectures. I gave birth just two weeks after I finished filming.

How was that? The lectures, not giving birth...

Amazing! The funny thing was that when they emailed me to ask if I was interested, I presumed the message was a joke, so I deleted it. Luckily, they contacted me again a few days later and asked for my ideas.

What did you pitch them?

I wanted to show people how creative engineering can be. I wanted to set some big, wacky challenges that would make people go, ‘Wow, was that engineering?’ We ended up talking to an astronaut in space and turning the Shell Centre in London into a giant game of *Tetris*. The whole experience was life-changing.

How so?

I do a lot more public engagement and media work now. We recently devised a citizen-engineering project where we got people to build musical robots from recycled objects. The




Robot Orchestra was born. It’s going to be at Cheltenham Science Festival and on Radio 1’s *Live Lounge*.

But how are you at changing light bulbs?

Good. I’m very handy in the house. I’m thinking about designing an invisible infrared fence for my L-shaped garden so if my daughter goes round the corner where I can’t see her, an alarm will sound.

What do you worry about?

I worry we’re so busy protecting our children that we don’t allow them to fail. But there is so much to be learned from failure. Children should be allowed to tinker and get things wrong. It helps to build confidence, resilience and the natural skills that underpin innovation. 

Prof Danielle George is

professor of radio frequency engineering at the University of Manchester.

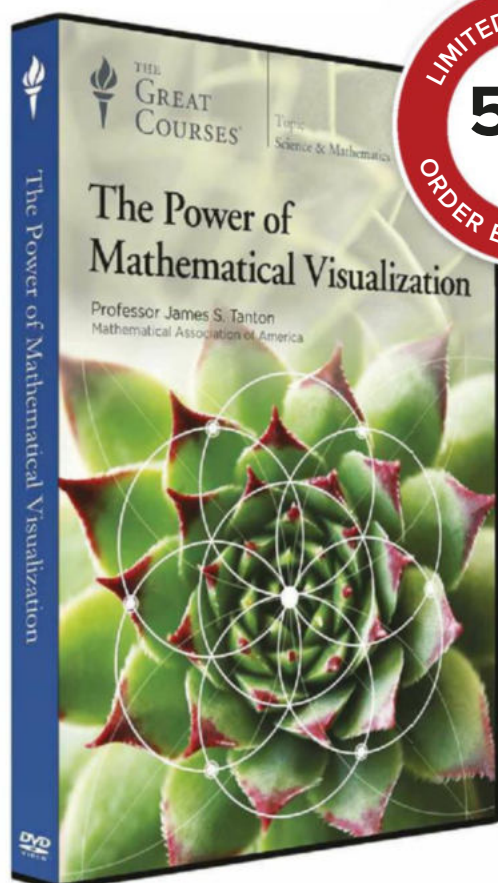
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